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ADEQUACY OF M16A1 RIFLE PERFORMANCE AND ITS IMPLICATIONS FOR MARKSMANSHIP TRAINING

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U. S. Army

Research Institute for the Behavioral and Social Sciences

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document records firing test results for typical M16A1 rifles, providing data for simplified and improved marksmanship training procedures. Sixty rifles were selected at random and subjected to bench-type serviceability checks and accuracy firing tests. Following initial testing, a representative sample (good, average and bad) of nine rifles was selected for the following tests: zero procedures, zeroing with the long range sight, trajectory, rimfire adapter, effects of barrel stress, firer error and firing by initial entry soldiers. This document is intended for marksmanship training developers and

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proponents of marksmanship hardware items. It should also be of value to those who want to become more knowledgeable about the capabilities of the M16A1 rifle.

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M16A1 Rifle Performance

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

This report is one of several provided by the Mellonics Systems Development Division of Litton Systems, Inc., to the Army Research Institute for the Behavioral and Social Sciences (ARI) under Contract DAHC 19-77-C-0011.

ARI Research in marksmanship training systems development is conducted as an inhouse effort augmented by contracts with organizations selected as having unique capabilities for research in the area. The Mellonics effort supports the Training Effectiveness Analysis (TEA) research being conducted by the Fort Benning ARI Field Unit involving the effectiveness of training for basic rifle marksmanship skills. Previous TEA efforts have resulted in eight reports pertaining to marksmanship.

This effort provides data concerning the performance quality of typical service rifle/ammunition combinations and compares theoretical information with the actual performance of typical service rifles. Simplified and more efficient techniques of teaching basic marksmanship skills are tested and the relative contribution of various fundamental factors to shooting performance are investigated.

The research was coordinated with the United States Army Infantry School, the proponent agency for M16A1 rifle marksmanship training program development.

Appreciation is extended to the U. S. Army Marksmansip Training Unit for making test facilities and personnel available to support this test.

The project was conducted as part of Army Project 2Q763743A773, FY 78 and FY 79 Work Program. It was directly responsive to the requirements of FORSCOM, USAIS and TRADOC.

JOSEPH ZEIDNER
Technical Director

ADEQUACY OF M16A1 RIFLE PERFORMANCE AND ITS IMPLICATIONS FOR MARKSMANSHIP TRAINING

BRIEF

Requirement:

To determine the quality of firing performance for the typical M16A1 rifle and test theoretical training and ballistics information. To develop a better understanding of the Man/Weapon interface and develop simplified and improved training procedures.

Procedure:

Research objectives were organized into nine different firing tests. During the period 7 March to 13 April 1979, some 5000 rounds of ammunition were fired through 60 M16A1 rifles at Fort Benning, Georgia.

Findings:

The typical M16A1 rifle is capable of effectively engaging personnel size targets out to a range of 300 m when standard serviceability checks are augmented with firing tests to assure weapons quality. Theoretical information pertaining to zero procedures and bullet trajectory is accurate. Using the long range sight and adjusting bullet impact to point of aim at 25 m produces a 250 m battle sight zero. This procedure also provides for meaningful skill practice on the 25 m range. The rimfire adapter is not adequate for attaining a weapons zero and results in an increased shot group size. Various types of external stress on the rifle (hasty sling, bipod, etc.) have a significant effect on the strike of the bullets. Some forms of firer error currently receiving emphasis, e.g., sight misalignment, have minimum effect on the strike of the bullet.

Utilization of Findings:

The information in this report is totally applicable to all M16A1 rifle marksmanship programs and, to some degree, all marksmanship programs. It should also be of interest to the proponent of the rimfire adapter and personnel responsible for establishing ammunition quality control standards or serviceability procedures for the service rifle.

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ADEQUACY OF M-16A1 RIFLE PERFORMANCE AND ITS IMPLICATIONS FOR MARKSMANSHIP TRAINING

INTRODUCTION

Since its adoption as the standard service rifle, the M-16 has been subjected to considerable criticism concerning its reliability and performance capabilities. The purpose of this current effort was to determine the accuracy and performance characteristics of the typical M-16 rifle currently in the hands of the basic trainee and to examine trajectory information and current training procedures. The U. S. Army adopted the TRAINFIRE concept of rifle marksmanship in the late 1950's. This program resulted from the recognition of the importance of training transfer, i.e., the transfer of skills learned in training to those used in combat. The initial TRAINFIRE program was designed for maximum rapid transfer of shooting skills to combat conditions. The basic concept of TRAINFIRE has changed little since its adoption; however, the amount of time allowed for the training program, the time devoted to marksmanship fundamentals, the procedures to provide downrange feedback, and the allocated training ammunition have varied significantly. In general, the trend has been to allocate fewer hours and rounds to each phase of training. Current programs place limited emphasis on marksmanship fundamentals and, except for the initial 25 meter firing for zero, no precise feedback of downrange results is provided in the program.

A 37-hour Program of Instruction, published by the Infantry School in April 1977, currently provides guidance to all Army Training Centers conducting basic rifle marksmanship training.

Litton-Mellonics, under contract to the Army Research Institute (ARI), is supporting the Training Effectiveness Analysis (TEA) research being conducted by the Fort Benning ARI Field Unit involving the effectiveness of training for basic rifle marksmanship skills. Research efforts under the current contract have resulted in eight reports which address a broad spectrum of marksmanship fundamentals.

This report addresses marksmanship training variables associated with the rifle and established training procedures. There are three basic elements that determine shooting accuracy - the rifle, the ammunition, and the soldier. To develop marksmanship fundamentals that emphasize the factors critical to good shooting and to establish realistic marksmanship standards for the soldier, reliable information is required concerning the peculiarities of the M-16 rifle and the capability of the rifle/ammunition combination available to the typical trainee. The M-16 rifle is not used by competitive shooters and the absence of downrange feedback in the standard instructional program contributes to a general lack of knowledge concerning the performance of the M-16 bullet at ranges beyond 25 meters. Most of the firing performance data available is based on theoretical computations or is based on firings through test barrels or with weapons in 'like new' condition. No reliable data was available which provided the required information on the performance capability of the typical M-16 rifle used by trainees in Army Training Centers.

OBJECTIVES

The development of a new Basic Rifle Marksmanship (BRM) Program of Instruction (POI) required definitive answers to several questions concerning weapons quality and the accuracy of established procedures. The following objectives were selected and organized into nine tests to provide the required data:

- o Determine the serviceability and accuracy of a large sample (60) of typical M-16A1 rifles used by basic trainees. Select a smaller, representative sample (6 to 9) of weapons for use in subsequent tests.
- o Confirm the current 250 meter battle sight zero procedure (adjusting the center of the shot groups to 2.4 centimeters below point of aim at 25 meters).
- o Test a new procedure for obtaining a 250 meter battle sight zero at 25 meters (using the long range sight and adjusting the center of shot groups to point of aim at 25 meters).
- o Confirm trajectory information for 150, 250, and 300 meters.
- o Compare the firings of .22 caliber ammunition utilizing the rimfire adapter with the firing of service ammunition.
- o Evaluate the effects of external stress on the rifle (hasty sling, bipod, etc.).
- o Evaluate the effects of various firer errors on the placement of shots (eye relief, sight alinement, cant, etc.).

- Evaluate the effects of hard trigger pull and target type (standard Canadian bull vs. scaled silhouette) on the firing performance of trainees.

GENERAL PROCEDURES

The live firing tests reported herein were conducted at Fort Benning, Georgia, during the period 7 March to 13 April 1979. Each test report includes details of the procedure for that particular test, but the following details pertain to all tests.

Military 5.56 ball ammunition, M-193, Lot LC-2-421, was used in all tests. The Small Arms Quality Manager and the Quality Assurance Procedures Branch Chief, Lake City Army Ammunition Plant, stated that this was a representative lot of ammunition. The acceptance data for the lot of ammunition is included as Appendix A.

Weather information, including temperature, humidity, and barometric pressure, was recorded during each test. However, for the target ranges used, correcting the ballistic coefficient on the basis of atmospheric conditions was considered as having little effect on the test outcomes since other variables or potential sources of random variability (e.g., sighting error) were thought to exert much more influence on firing performance. Moreover, most comparisons were made within, rather than across, tests, so it is highly unlikely that such a correction would have measurably influenced the overall results.

Although the effect of wind on bullets is a significant variable, the configuration of the outdoor test facility (Parks Range) precluded corrections to data due to wind effects. Because most questions of interest in these tests related to variations in the vertical plane, the results focus primarily in that dimension of bullet placement on targets. Only under controlled conditions of wind production could the effects of wind have been adequately measured. This consideration, coupled with the absence of a specifically designed downrange wind velocity measuring system at Parks Range, precluded either the study of, or correction for, wind effects on bullets.

Finally, the results are reported in terms of mean shot group size and displacement of centers of shot groups. This method was chosen for two reasons. The first is because the statistical comparison of conditions within the tests requires some form of measure of central tendency. In some cases, empirical data were compared to theoretical values which cannot be done on a weapon-by-weapon basis. In all cases, however, the mean of a shot group characteristic was chosen as a representation of the performance of the group of selected rifles. Since the weapons formed a random sample of the population of M-16A1 rifles, the mean performance was regarded as the best estimate of that performance parameter for the population. In other words, the results reported can be interpreted to mean that the best guess of how any M-16A1 chosen at random will perform under specified conditions is the mean reported below for these conditions.

The authors recognize the limitations of average performance, since it may not represent the actual performance of any given weapon. When averaged data are felt not to reflect adequately the outcome of a test, alternative methods of displaying the results are employed. In some cases, a weapon-by-weapon analysis is included. Since the authors recognize the limitations of any method which summarizes a collection of individual observations, all raw data are included in Appendices.

All photo reproductions of 25 m zero targets in this report were reduced by 50% after cutting away target portions not containing hits. All 25 m targets are the actual targets fired during the test. The bullet strikes on targets at greater ranges are accurately represented by the outline of an "E" type silhouette. When a bulls eye target was used, the silhouette has been added to assist in the evaluation of weapon performance.

TEST 1: ACCURACY AND SERVICEABILITY

The objective of Test 1 was to select a representative sample of M-16A1 rifles issued to trainees by using standard Army serviceability test procedures and live firing tests.

PROCEDURE

Selection of the sample. Two sources of M-16A1 rifles currently in use at Fort Benning, Georgia, were used for testing. The first was the Kelley Hill weapons pool containing a total of approximately 2,000 M-16A1 rifles that are issued to or used in support of resident student classes. On the day selection was made, 302 rifles were available from which 30 were chosen at random. The second source of weapons was the arms room of C Company, 7th Battalion, 1st Advanced Individual Training Brigade, which contained approximately 250 weapons. Of the weapons available the day selection was made, 30 were chosen at random.

All sixty weapons were selected by the authors without consideration of any identifiable rifle characteristic. Noteworthy are the facts that weapons pool and arms room personnel could not identify "good" or "bad" weapons when requested to do so, nor did any personnel attempt to influence the choice of weapons. Since records of how long weapons have been in service, or the amount of ammunition they have fired, are not maintained locally, no definitive information on usage was available. However, C Company personnel stated their rifles had gone through three training cycles since being reconditioned. Some of the Kelley Hill weapons, as indicated by the worn finish and old type (open) flash suppressor, had been in continuous service for several years. The sixty test weapons were secured in the arms room of the United States Army Marksmanship Unit (AMU) throughout the testing period.

Bench Tests. The following data were recorded for each weapon: serial number, manufacturer, local source of weapon, and type of flash suppressor. Utilizing the direct and general support test gages, each weapon was checked for barrel straightness (Gage, Straightness: Barrel Bore FSN 4933-221-9391), proper head space (Gage, Headspace FSN 4933-070-7814) and bore erosion (Gage, Barrel Erosion FSN 4933-912-3409) by experienced AMU personnel. The AMU device for determining the pressure required to pull the trigger (a crooked rod with removable weights which is placed on the trigger) was used to check trigger pull to the nearest half pound.

Following the final selection of nine weapons as described below, AMU personnel measured bore diameter. This was accomplished by pouring a liquified metal mixture into the chamber end of the barrel, allowing the mixture to harden, and removing it. The plug was then measured with a micrometer, resulting in a measure of bore diameter approximately 5 cm from the chamber.

Following the completion of all firing tests, the nine weapons were inspected by personnel of the Fort Benning Direct/General Support Small Arms Repair Shop. Three mechanical checks were repeated: barrel straightness, head space, and bore erosion. Additionally, the weapons were checked with the muzzle erosion gage (Gage, Muzzle Erosion FSN 5220-155-4925).

Firing Tests. Live fire tests were conducted at Parks Range, Fort Benning, Georgia, an outdoor weapons test facility maintained by the United States Army Marksmanship Unit (AMU). Each weapon was placed in a rifle cradle, a heavy viso-like mechanism which secures the rifle at the butt and forward sling clip. Five rounds were fired to settle the weapon before a final tightness check of the rifle. A three-round shot group was fired at a target placed 25 meters from the muzzle. Muzzle velocity was measured with an Oehler Research Chronograph (Model 33) as specified by the manufacturer's instructions. All cradle tests were conducted by an AMU weapons test expert. Subsequent to the cradle firing, the weapons were fired by two individuals with competitive shooting experience. Each firer shot three rounds at an ARI zeroing target (Appendix B) placed at 25 meters. All individual firer shot groups were fired from the prone, unsupported position. Order of firing was varied systematically to counterbalance the effects of fatigue.

RESULTS

Shot group sizes for the cradle and the two firers were recorded. Shot group size was defined as the largest center-to-center distance measured on pairs of the three bullet holes. One weapon was eliminated because of a weak hammer spring. The data on the remaining 59 rifles are included as Appendix C. It should also be noted that the mean performance of Firer 1 was considerably better than Firer 2.

Once these data were obtained, a second selection process was conducted to obtain a manageable, but representative, subsample of rifles for further tests. Since the weapons could not be differentiated on the basis of bench tests which all weapons passed, the selection criteria were limited to shot group size, mean muzzle velocity, standard deviation of muzzle velocity, and trigger pull. An overall comparison of Kelley Hill weapons with AIT weapons revealed a higher mean muzzle velocity for the AIT weapons (AIT: 3162 ft/sec; Kelley Hill: 3136 ft/sec; $\underline{t} = 3.16$, $\underline{df} = 57$, two-tailed $\underline{p} < .003$). In addition, the AIT weapons evidenced a statistically smaller mean shot group size ($\underline{M} = 1.79$ cm) than the Kelley Hill weapons ($\underline{M} = 2.43$ cm; $\underline{t} = 2.04$, $\underline{df} = 57$, two-tailed $\underline{p} < .05$). However, the apparent relationship between mean muzzle velocity and shot group size was not substantiated when the two variables were correlated for individual weapons ($\underline{r} = .11$, $\underline{p} > .05$). Additional Pearson correlational analyses revealed no statistically significant relationships between firer shot group size (prone unsupported) and trigger pull ($\underline{r} = -.15$ and $\underline{r} = .03$, for firers 1&2 respectively, both two-tailed $\underline{p} > .05$) or between the standard deviation of muzzle velocity and cradle shot group size ($\underline{r} = -.15$, two-tailed $\underline{p} > .05$).

Given the absence of a definitive pattern of interrelationships in the data, the final selection of the subsample was accomplished with the use of frequency distributions of cradle shot group size, muzzle velocity, and trigger pull (Figures 1, 2, and 3). Since subsequent tests were to use the size and placement of shot groups as data, the primary selection criterion was shot group size. Six weapons were chosen which represented a stratified sample of the distribution of 59 shot groups (Figure 1). Table 1 lists the choices, together with three additional weapons chosen as spares. Note that 83% of the weapons in the sample of 59 evidence shot group sizes in the range from .4 cm to 2.7 cm; likewise, 5 of the 6 weapons (83%) finally selected fired cradle shot group sizes in that range. Weapon No. 51 was deliberately chosen as a poor weapon to complete the subsample. The final choice of the six weapons was influenced to a lesser degree by muzzle velocity and trigger pull. Weapons choice was narrowed so that the final sample fell in the most frequently occurring categories of muzzle velocity and trigger pull. As nearly as possible, the six test weapons (plus the three spares) reflected differences in manufacturer, Fort Benning source of rifles, and the type of flash suppressor (which dates the weapon as to time of initial issue or last reconditioning). Descriptive statistics of the final subsample are summarized in Table 2. Figure 4 shows photo reductions of the actual shot groups of selected weapons.

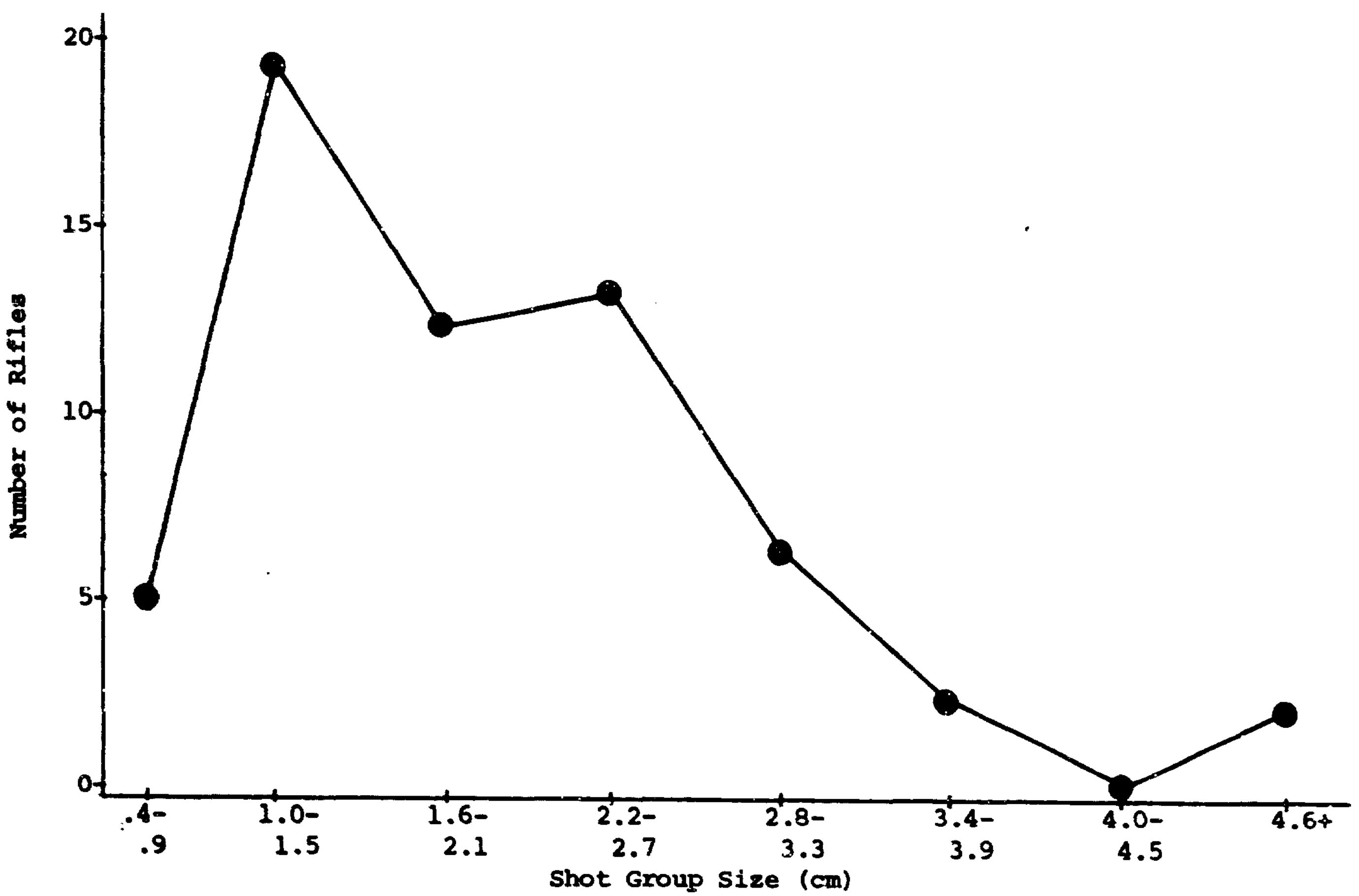


Figure 1. Frequency distribution of shot group size for sample of 59 rifles.

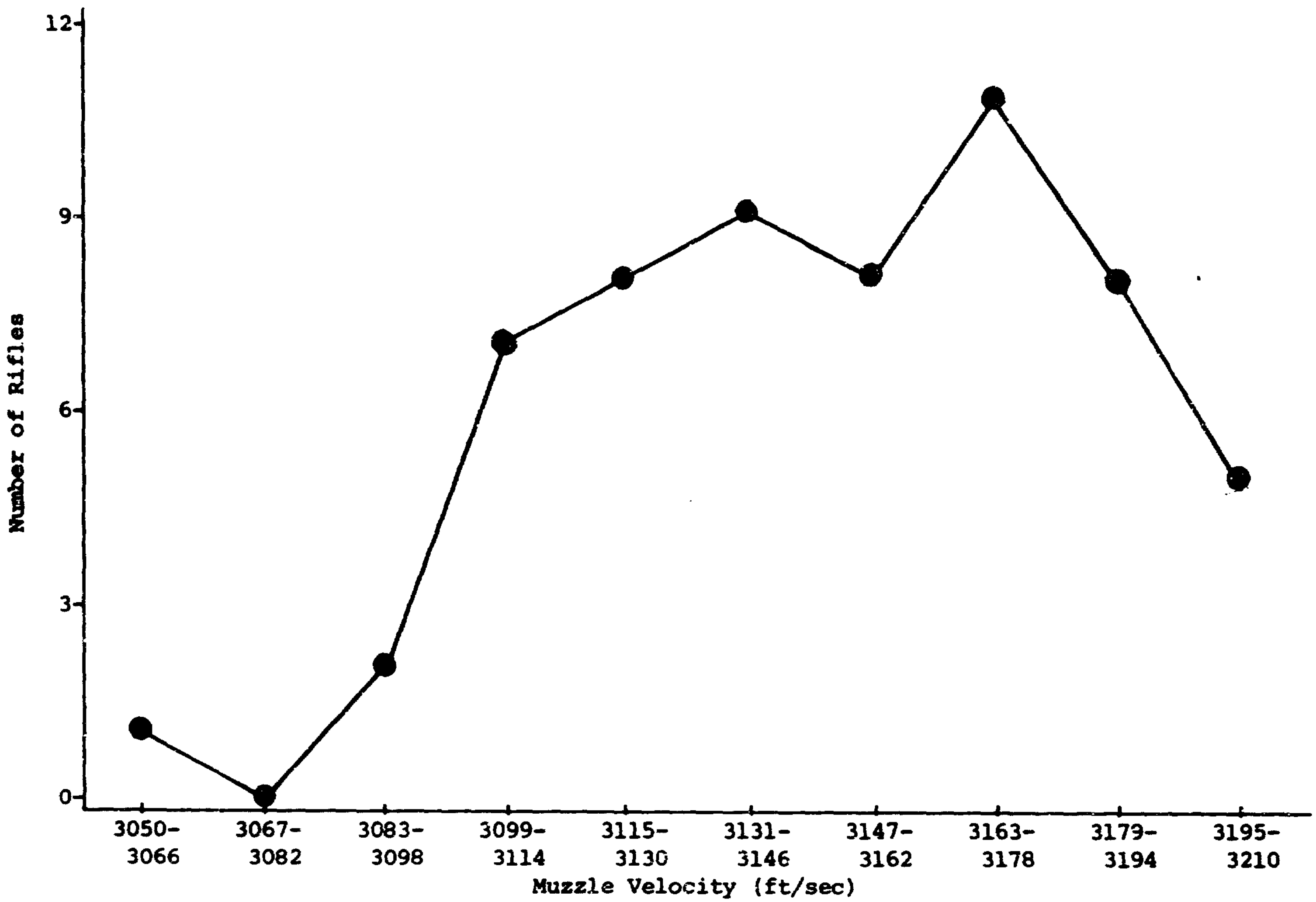


Figure 2. Frequency distribution of muzzle velocity for sample of 59 rifles.

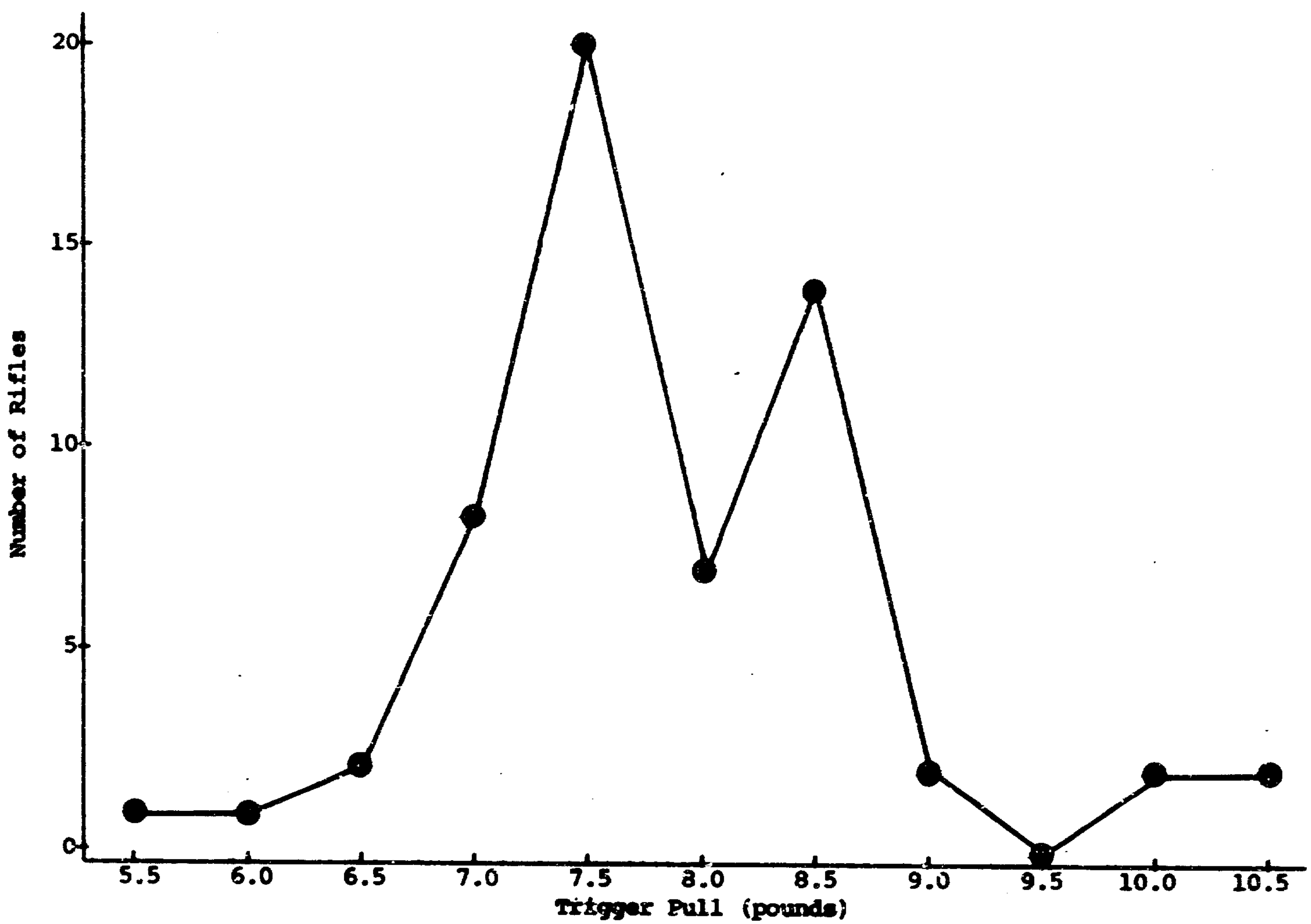


Figure 3. Frequency distribution of trigger pull of sample of 59 rifles.

TABLE 1

Bench and Firing Test Measurements on Nine Weapons Used in Subsequent Tests

Weapon No.	Flash Suppressor	Source[1]	Standard Army Tests: Barrel Straightness	Standard Army Tests: Head-space	Standard Army Tests: Bore Wear	Bore Diameter[2]	Mean Muzzle Velocity[3]	Trigger Pull[4]	Shot Group Size[5]: Cradle	Shot Group Size[5]: Firer 1	Shot Group Size[5]: Firer 2
9	Closed	AIT	OK	OK	OK	.2248	3124	7.5	1.4	1.5	3.3
11	Closed	AIT	OK	OK	OK	.2250	3146	8.5	1.1	.8	3.8
17*	Closed	AIT	OK	OK	OK	.2253	3184	10.5	.4	1.8	4.6
35	Closed	K.H.	OK	OK	OK	.2251	3100	8.5	2.1	3.0	2.7
41	Closed	K.H.	OK	OK	OK	.2249	3187	7.5	2.5	2.8	2.8
51	Open	K.H.	OK	OK	OK	.2257	3167	8.5	8.8	6.7	7.9
52*	Open	K.H.	OK	OK	OK	.2249	3135	5.5	1.3	2.9	1.5
57*	Open	K.H.	OK	OK	OK	.2257	3129	7.5	2.8	1.7	1.9
58	Closed	K.H.	OK	OK	OK	.2250	3151	8.5	1.5	2.9	4.5

* Identifies spare weapons

[1] AIT = Advanced Individual Training K.H. = Kelley Hill

[2] inches

[3] feet/second

[4] pounds (TM9-1005-249-34 specifies a 5 pound minimum and an 8.5 pound maximum.)

[5] centimeters

TABLE 2

Descriptive Statistics of Selection Criteria of Test Weapons

		Full Sample	Sample of 9	Sample of 6
Manufacturer*	Colt	23	5	4
	GM**	36	4	2
Flash Suppressor*	Open	11	3	1
	Closed	48	6	5
Source of Rifle*	Kelly Hill	30	6	4
	AIT Bde	29	3	2
Mean Shot Group Size (cm)	Cradle	2.11	2.43	2.90
	Firer 1	2.44	2.68	2.95
	Firer 2	3.63	3.67	4.17
Mean Bore Diameter (inches)		----	.2252	.2251
Mean Muzzle Velocity (ft/sec)		3149	3147	3146
Mean Trigger Pull (pounds)		7.90	8.00	8.20

* Numbers refer to the number of rifles in each category

** General Motors

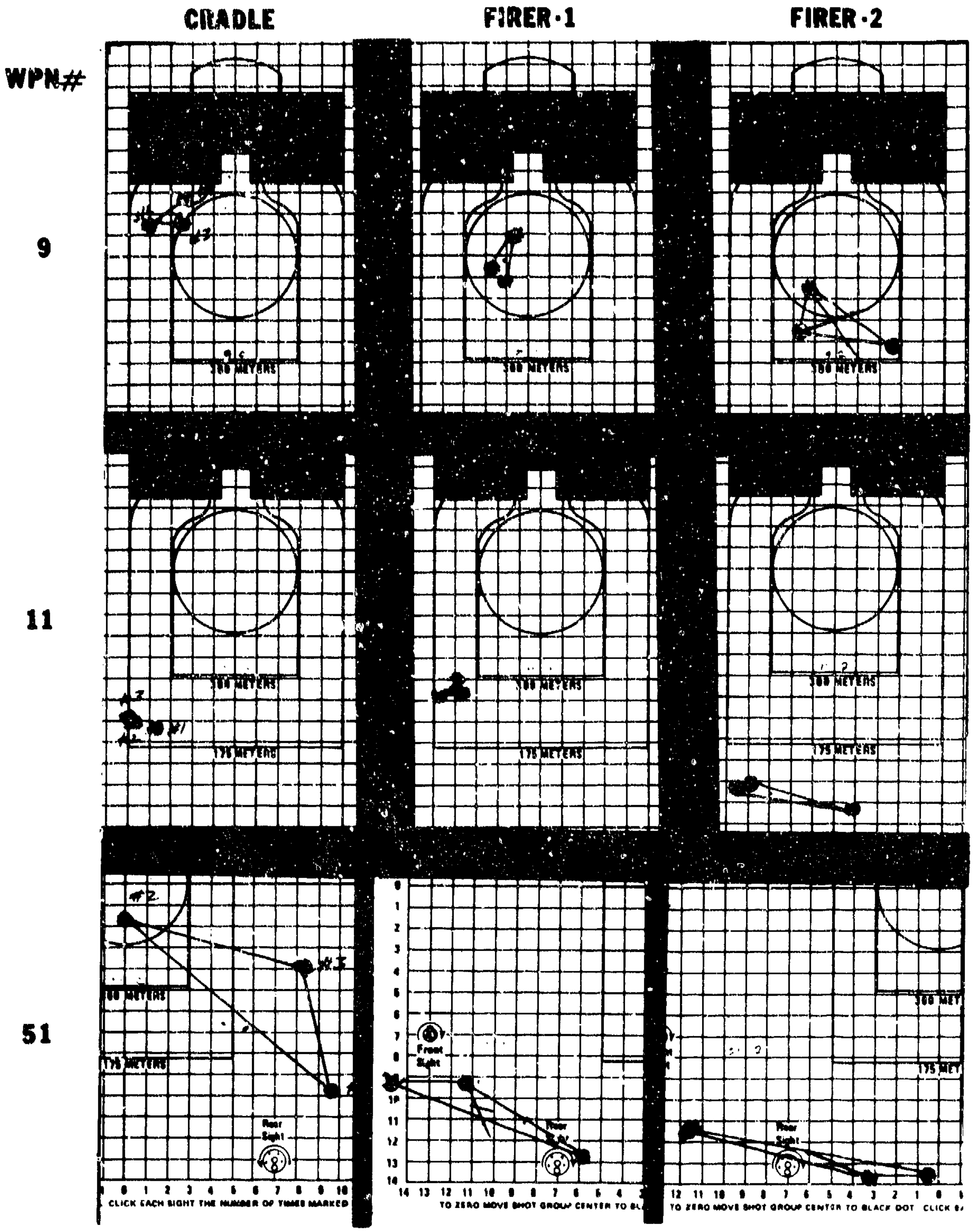


Figure 4: Shot Group Targets. Firer 1 and 2 fired from prone unsupported positions. Note the large groups fired by Weapon 51.

DISCUSSION

Of considerable interest is the finding that the standard serviceability checks, muzzle velocity, and trigger pull were not correlated with shot group size. Without exception, all weapons passed the serviceability checks. This speaks well for direct support and general support maintenance. However, the fact that all weapons received the same score of "Pass" (on a Pass/Fail scale) on the three bench tests precludes any attempt to statistically associate the bench test data with other rifle performance data.

By establishing shot group size as the measure of rifle performance, the expectation was that muzzle velocity and trigger pull would emerge as major variables associated with differences in shot group size. Muzzle velocity was expected to be inversely related to shot group size in that high values of muzzle velocity would be associated with small shot groups. Moreover, muzzle velocity and its variability from round to round might well have been indices of bore erosion, a major factor of rifle age and usage. A direct relationship between trigger pull and shot group size was anticipated to emerge from the data to reveal heavy trigger pull associated with large shot groups when individuals fired from unsupported positions.

The lack of correlation of these two variables with shot group size may be related to the fact that neither variable showed a wide range of values in the sample. However, given the values existing in this sample of rifles, muzzle velocity and trigger pull did not affect shot group size at 25 meters.

Of considerable concern, however, is not only the problem of describing weapons differences on the basis of practical physical measurements, but also the problem of selecting out those weapons which would result in the average trainee failing to zero the weapon or to engage field fire targets effectively. This latter problem is clearly illustrated by Weapon 51 which fired a cradle shot group size of 8.8 cm. None of the physical measurements completed in Test 1 isolate this weapon as a poorly performing weapon. Only a live fire test--a three round shot group--identified the weapon as one of marginal utility.

As will be shown in data to follow, various trends in performance emerged, none of which was predictable from the initial standardized tests performed in Test 1. But the results of Test 1 demonstrate that the available mechanical checks of the rifle are not exhaustive (i.e., others may need to be developed), nor are they predictive of rifle performance.

TEST 2: ZERO PROCEDURES

The primary objective of Test 2 was to demonstrate the accuracy of the current 250 meter battle sight zero (BSZ) procedure. The secondary objective was to examine the possibility of obtaining a 250 meter BSZ at 25 meters with the use of the long range sight.

PROCEDURE

Each of the six test weapons and the three spare weapons was tested from the cradle throughout Test 2. After the rifle was placed in the cradle, five rounds were fired to settle the weapon prior to making final adjustments to secure the weapon. The placement of the rifle in the cradle, firings, tightness adjustments, and sighting the weapon on 25 m and 250 m targets were done by the USAMU weapons test expert at Parks Range. Alinement of the front and rear sights and sight adjustments also were done by the weapons expert. However, alinement of the sights and the target was verified for each firing by a second observer with considerable service rifle experience.

Once the weapon was secured, a magazine containing 5.56 mm ball ammunition was fed into the weapon. The sights were alined with the bottom of the Canadian bull on the ARI zeroing target (Appendix B). After the initial three round shot group was fired, the required sight changes were made and recorded, and the weapon refired. This procedure was repeated until the center of the shot group was within ±.7 cm vertical and horizontal distance from the center of the zeroing circle (i.e., until the weapon was zeroed to within one click of elevation and windage of zero). The center of the shot group was determined by taking the arithmetic mean of the horizontal displacements of the rounds from the intended point of impact. The average vertical displacement of the same rounds was similarly determined. These two measures provided the rectangular coordinates of the center (centroid) of the shot group. Intended point of impact was defined as: (a) the center of the zeroing circle of the ARI zeroing target when engaged at 25 m with the regular sight, (b) same as the aiming point on the ARI zeroing target when engaged at 25 m with the long range sight, and (c) the center of the innermost ring of a 50 yard standard American pistol target when engaged at 250 m with the regular sight (facsimile at Appendix D). With the weapon zeroed, the 25 m target was removed and a 50 yard pistol target mounted at 250 m in an open area. Once the weapon was reaimed, a five round shot group was fired. The 250 m target was then removed, another ARI target was mounted at 25 m, the long range sight rotated up, the weapon aimed at the bottom of the Canadian bull, and a five round shot group fired. During neither the 250 m nor second 25 m firing phases were elevation or windage changes made to the rifle sights. However, on a few occasions, a 25 m or 250 m target was refired when post-firing checks indicated possible sight alinement errors resulting from misadjustment of the cradle.

RESULTS

The principal findings are shown in Table 3. The mean shot group sizes (regular sight and long range sight) at 25 m of the six rifle test group were, as expected, not significantly different statistically ($t < 1$). The same comparison for the nine weapon test group yielded the same result ($t < 1$). A comparison of mean shot group size at 25 m (regular sight) with mean shot group size at 250 m revealed an increase by a mean factor of 7.14 for the six rifles and a mean factor of 8.65 for the nine rifles. Since a simple geometric interpretation of shot group size differences implies that 250 m shot groups should be 10 times the size of shot groups at 25 m, the data from Test 2 were used to evaluate this theoretical relationship. In order to do so, the shot group size at 25 m for each rifle was multiplied by 10. The mean of this transformed 25 m data was compared to the mean of the obtained 250 m shot group size. For the six rifle sample, the difference between "theoretical" and obtained 250 m shot groups was statistically significant, $t = 4.72$, $df = 5$, two-tailed $p < .01$, whereas the same comparison for the nine rifle sample was not, $t = 1.37$, $df = 8$, two-tailed $p > .05$. In all but one of the nine rifles, 10 times the 25 m shot group size was greater than the 250 m shot group size. As can be seen in Table 3, multiplying the 25 m mean shot group size (regular sight) by 10 overestimates the mean shot group size at 250 m by at least 15%.

Of primary concern in this test was determining whether a weapon zeroed at 25 m attains a battle sight zero (BSZ) for 250 m. Table 3 reveals that the average center of shot groups for the six rifle sample was 1.28 cm above intended point of impact. Adding the data of the three spare weapons resulted in the vertical displacement of shot groups to average 3.57 cm below intended point of impact. This disparity was due to rounds of two of the spare weapons hitting three to four times lower than those of the other weapons. However, assuming vertical displacement of the point of bullet impact to be 0 cm from the point of aim at BSZ, the average vertical displacement of neither the six weapon group ($t < 1$) nor the nine weapon group ($t < 1$) showed a statistically significant departure from that value. An inspection of the individual

TABLE 3

Mean Shot Group Size and Horizontal and Vertical Displacement of Center of Shot Groups for Test 2

Sample Size	Target Range & Type of Sight	Mean Shot Group Size	Mean Shot Group Displacement Vertical	Horizontal
	25 m Regular	2.98 (1.62)	- .25 (.69)	+ .05 (.05)
6	250 m Regular	21.87 (14.69)	+ 1.28 (7.08)	+ .32 (12.93)
	25 m Long Range	3.50 (1.84)	+ .43 (1.06)	- .13 (.69)
	25 m Regular	2.67 (1.37)	- .40 (.60)	+ .15 (.56)
9	250 m Regular	22.65 (13.23)	- 3.57 (11.55)	+ 2.66 (11.24)
	25 m Long Range	2.98 (1.71)	+ .06 (1.17)	+ .37 (.96)

Note: All tabled values, except range, are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -. Numbers in parentheses are standard deviations.

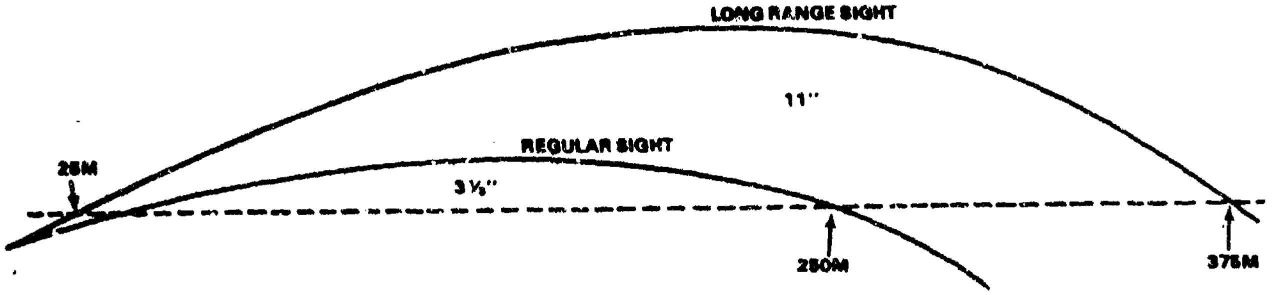
vertical displacements of the weapons (Appendix E) showed that six were zeroed to within one click (7 cm) of elevation at 250 m. The remaining three were zeroed within the range of 1-1/2 to 3-1/2 clicks of elevation at 250 m. As can be seen in Table 3, the vertical displacement of shot groups at 25 m was approximately .3 to .4 cm, indicating the weapons were adequately zeroed for that range (i.e., within the one click zeroing criterion). Figure 5 includes an illustration of the placement of rounds on the pistol target for some weapons. The outline of an "E" type silhouette is also shown to give an indication of where the rounds would have struck on silhouette targets.

An additional finding was that point of aim and point of impact of the bullet coincided at 25 m when the long range rear sight was utilized. The data in Table 3 show that vertical displacement errors were negligible with the use of the long range sight. Note that this measurement was taken from the point of aim on the ARI target (Appendix B) and not the center of the zeroing circle. Use of the long range sight, therefore, appears to effectively move the point of impact up 2.4 cm at 25 m. Figure 5 includes zero targets that were fired utilizing the long range sight.

DISCUSSION

The objective of this test was to determine whether the use of the ARI target at 25 m with the regular sight adequately zeroed the weapon for 250 m BSZ. This was found to be the case. But the consideration influencing the test of the long range sight at 25 m was to determine whether, functionally, point of aim can be made to coincide with point of impact at 25 m.

The bottom curve on the sketch below shows the trajectory produced when the rifle is zeroed for 250 m using the regular sight - 2.4 cm low at 25 m and the same as line of sight at 42 and 250 m. When the regular sight is zeroed for 250 m, the long range sight is automatically



zeroed for approximately 375 m. Therefore, flipping up the long range sight after the rifle has been zeroed using normal procedures will result in the trajectory represented by the top curve on the sketch - with point of aim and bullet strike being approximately the same at 25 m and 375 m. Thus, a purpose of this test was to verify that the use of the long range sight results in point of aim coinciding with point of impact at 25 m. The data supported the supposition that the two points are functionally the same.

The training implication is obvious. The confusion a trainee may experience when his or her bullets do not strike the point of aim at 25 m (regular sight) can be eliminated through the simple expedient of zeroing with the long range sight. Whether zeroing to point of aim with the long range sight at 25 m results in a 250 m BSZ with the regular sight was investigated further in Test 3.

Finally, an incidental finding during the zeroing phase was that adjustments of six or less clicks of windage and elevation moved the center of the shot groups more than the prescribed 7 mm per click. As can be seen in Appendix F, movements of shot groups greater than 6 clicks moved the shot groups approximately 7 mm per click, as contrasted to approximately 11 mm per click with smaller changes. These findings are merely suggestive due to the limited number of observations. A possible explanation is that aiming error and rifle movement within the cradle account for only a small proportion of the total shot group to shot group distance observed after sight changes of many clicks. But the same amount of variability captures a much larger proportion of the movement associated with slight changes of a few clicks. Some future systematic sampling of sight changes and resultant shot group movements may not only verify the above finding, but may also result in an estimation of the magnitude of sighting errors and mechanical variability inherent in sight changes.

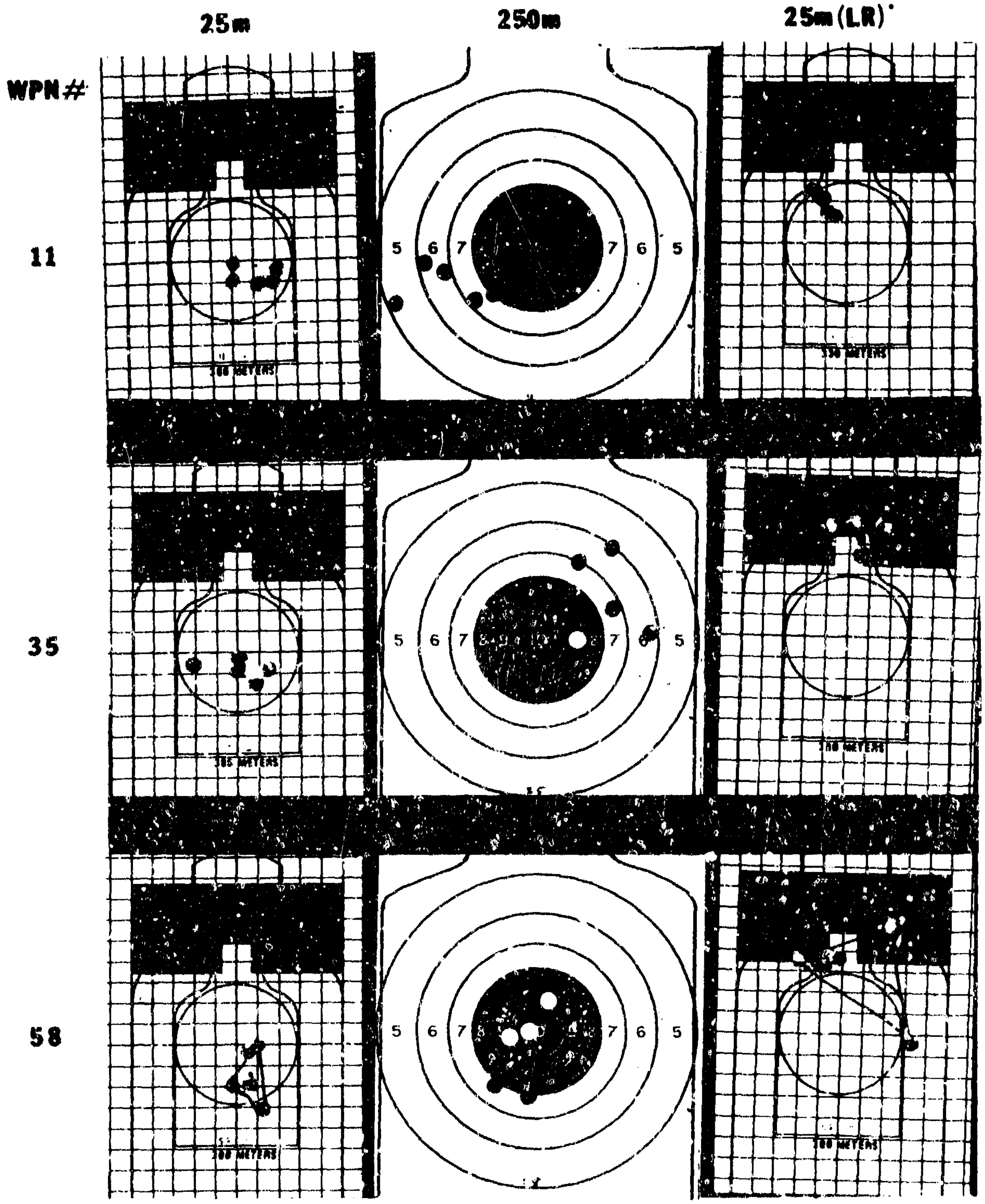


Figure 5: Zero Procedure Targets (Cradle). Targets at left reflect regular 25 m zero. Center targets show bullet strikes at 250 m. Targets at right were engaged using the Long Range Sight*.

TEST 3: ZEROING WITH THE LONG RANGE SIGHT

The objective of Test 3 was to examine the feasibility of zeroing with the long range sight and a scaled silhouette target to obtain a 250 m battle sight zero.

PROCEDURE

Data were obtained from both cradle firings and two experienced firers. All the procedural details of the cradle firings in Test 2 were followed with the following exception. Each of the six rifles was zeroed, using the long range sight, on a silhouette target scaled such that the perceived size and shape of the silhouette when viewed at a 25 m viewer-to-target distance was equivalent to the perceived size and shape of an "E" type silhouette viewed at 250 m viewer-to-target distance. Point of aim was a judgmental center of mass. An example of the zero target is included as Appendix G.

Once the weapon was zeroed to within 1 click of elevation and windage of center of mass, the regular sight was rotated up and a five round shot group fired at an "E" type silhouette target mounted at 250 m. The 250 m target was then removed and an ARI target placed at 25 m. Using the regular sight, a five round shot group was fired while aiming at the bottom of the Canadian bull.

The same sequence of events--long range sight-silhouette target zero, 250 and 25 m zero confirmations with the regular sight--was followed by the same firers from Test 1. Each fired the six weapons from a supported position.

RESULTS

To evaluate whether the zeroing process with the long range sight-scaled silhouette combination resulted in a 250 m BSZ, mean vertical displacement of shot groups at 250 m was contrasted to the theoretical value of 0 cm (i.e., no displacement of shot group centers from point of aim). For the six weapons, the mean vertical displacement of the cradle test was not a statistically significant departure ($t < 1$), nor were the shot groups of the two firers (for both, $t < 1$). Therefore, the statistical analysis indicates the group of rifles was adequately zeroed. The data are summarized in Table 4. Individual firing data are included at Appendix H. A sample of bullet hits at 250 meters is illustrated in Figure 6.

TABLE 4

Mean Shot Group Size and Mean Vertical and Horizontal Displacement of Shot Groups for Test 3

Firer	Range	Type of Sight	Type of Target	Mean Shot Group Size	Mean Shot Group Displacement Vertical	Horizontal
Cradle	25 m	Long Range	Silhouette	2.33 (1.06)	+ .08 (.69)	.00 (.95)
Firer 1	25 m	Long Range	Silhouette	3.02 (1.17)	- .22 (1.27)	+ .53 (.76)
Firer 2	25 m	Long Range	Silhouette	2.22 (.70)	+ .15 (1.04)	+ .58 (.41)
Cradle	250 m	Regular	Silhouette	22.75 (7.60)	- .55 (9.34)	- 1.72 (10.30)
Firer 1	250 m	Regular	Silhouette	26.22 (9.74)	- 2.40 (9.90)	+ 6.33 (15.18)
Firer 2	250 m	Regular	Silhouette	40.42 (11.61)	- .13 (11.71)	+ .77 (16.06)
Cradle	25 m	Regular	ARI	3.13 (1.48)	+ 1.13 (1.43)	+ .47 (.82)
Firer 1	25 m	Regular	ARI	2.68 (.93)	+ 1.05 (1.13)	+ .58 (.76)
Firer 2	25 m	Regular	ARI	4.55 (3.05)	+ 1.20 (1.19)	- .75 (.91)

Note: All tabled values, except range, are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -. Numbers in parentheses are standard deviations.

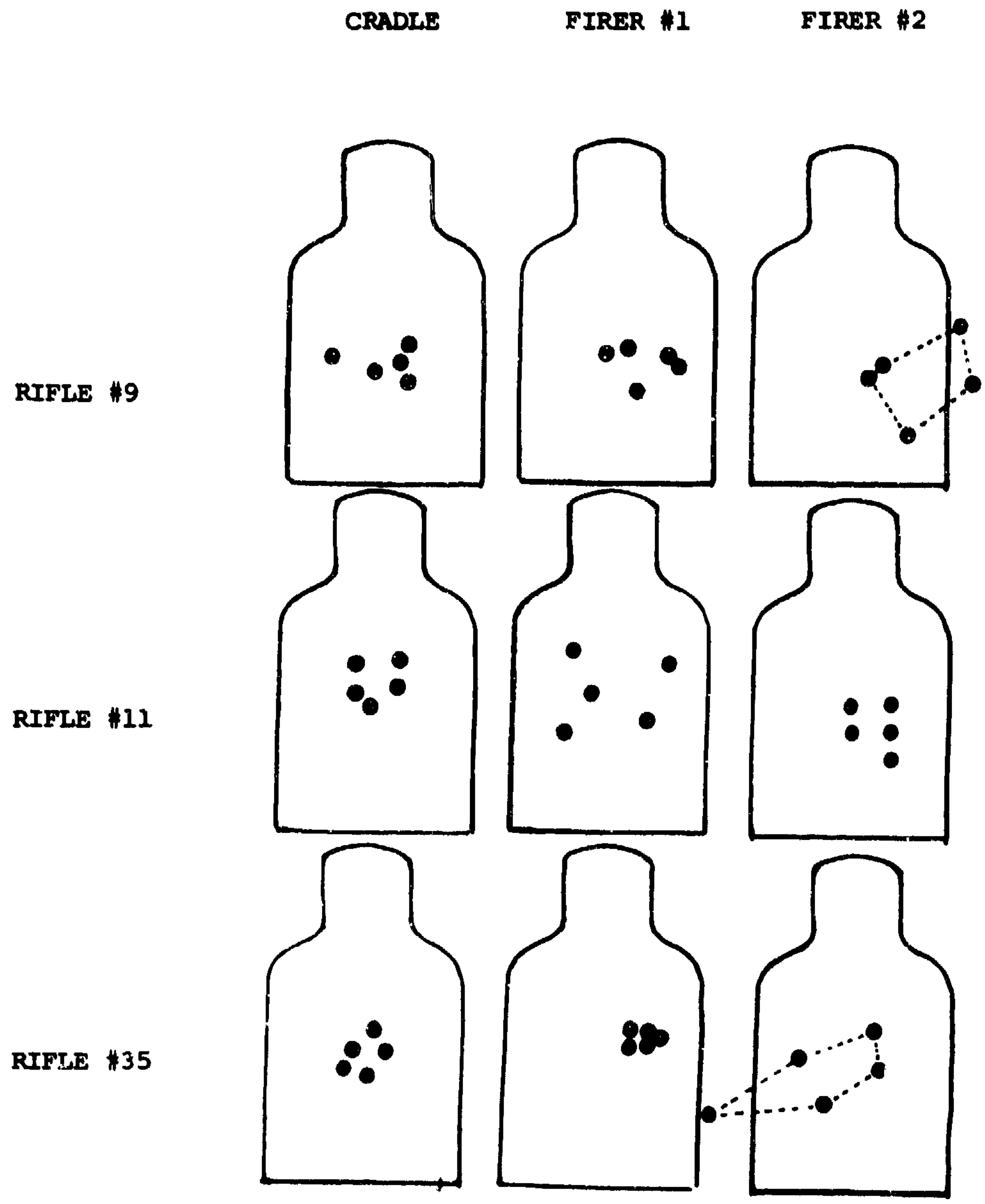


Figure 6: Placement of shots on "E" type silhouette at 250 meters, using regular sight, after adjusting sights to hit the center of a scaled silhouette target, using the long range sight, at 25 meters.

An additional consideration was whether point of aim functionally coincides with point of impact when the long range sight is used at 25 m. Analysis of this expectation based on theoretical trajectory calculations was accomplished with data from the silhouette firings. First, to determine the center of mass of the silhouette target, the longitudinal axis that bisects the horizontal axes of the figure was determined. The point on that line 42% of the distance from the bottom of the figure was chosen as the center of mass. This point was regarded as locating the center of mass at a point giving approximately an 1:3 ratio of head mass to body mass. Centers of shot groups were measured horizontally and vertically from that point.

Cradle and hand-held firings did not result in a significant vertical departure of shot group centers from center of silhouette mass for the cradle test ($\underline{t} < 1$) or either Firer 1 or Firer 2 ($\underline{t} < 1$ and $\underline{t} = 2.26$, $\underline{df} = 5$, two-tailed $\underline{p} > .05$, respectively). No significant horizontal departures were detected for the cradle firings ($\underline{t} < 1$) or Firer 1 ($\underline{t} = 1.71$, $\underline{df} = 5$, two-tailed $\underline{p} > .05$) or Firer 2 ($\underline{t} = 1.84$, $\underline{df} = 5$, two-tailed $\underline{p} > .05$). Under the assumption that the judgmental center of mass during the live fire tests is the same as the center of mass as defined above, the data support the notion that point of aim is functionally equivalent to point of impact at 25 m with the use of the long range sight.

To detect whether some unanticipated error might have been introduced with the long range sight, a final firing on the ARI target with the regular sight was conducted. No significant vertical departure of shot groups was found for cradle data ($\underline{t} < 1$), Firer 1 ($\underline{t} = 1.94$, $\underline{df} = 5$, two-tailed $\underline{p} > .05$), or Firer 2 ($\underline{t} = 2.50$, $\underline{df} = 5$, two-tailed $\underline{p} > .05$).

DISCUSSION

One hypothesis addressed by the data is whether the point of aim functionally coincides with point of impact when the long range sight is used to fire at 25 m targets. The qualifier "functionally" is used because of the variability of the shot groups about the intended point of impact. While the theoretical calculation places the strike of the bullet 1.5 mm above point of aim at 25 m (by implication, the strike of the bullet at 25 m when the long range sight is used and after the regular sight has been zeroed for 250 m), the standard deviation of shot group displacement about intended point of impact exceeded 1.5 mm. Thus, the level of precision necessary to test the theoretical value was not attained in this series of live fire tests. Therefore, it was assumed as a practical matter that point of aim functionally coincided with point of impact. With this limitation, the data supported the hypothesis.

The second hypothesis, that the zeroing process utilizing a silhouette target and the long range sight at 25 m yields a 250 m BSZ, was supported. A secondary finding was that the weapons subsequently fired well-placed shot groups on a standard 25 m target with the regular sight in place. These findings are encouraging, since bullets striking where the weapon is aimed is conceptually less confusing to a trainee. An additional observation was that expert firers appear to use the same point of aim on the unmarked silhouette targets. Whether naive firers could be so consistent was examined in Test 8.

Regardless of the target type used, utilizing the long range sight effectively moves the strike of the bullet up 2.4 cm at 25 m, and this is done by a simple rotation of the rear sight with no deleterious effect on the 250 m BSZ.

TEST 4: TRAJECTORY

The objective of Test 4 was to obtain trajectory information from weapons zeroed for 250 meters.

PROCEDURE

All weapons were fired from the cradle during all phases of this test. The weapons were rezeroed using the same personnel and procedure as in Test 2. Once the weapon was zeroed, 50 yard pistol targets were engaged at ranges of 250, 150, and 300 meters in that order. Only one target was engaged at a time, which necessitated cradle adjustments to realine the sights and target. The only subsequent sight changes were for 250 meters when required to obtain an adequate shot group elevation. After shot groups at range were obtained, zero was reconfirmed at 25 meters with an ARI target (Appendix B). Wind measurements were made at one location downrange. However, the configuration of Parks Range indicated a single measurement point could not adequately represent the wind current patterns acting on the bullet path. As a result, no corrections for the effects of the wind on bullets were made.

RESULTS

The data from the six test weapons (Table 5) indicated that at 150 m (approximately the maximum ordinate of the trajectory for 250 m BSZ) the centers of shot groups averaged 4.87 cm (1.9 in) above line of sight and at 300 m shot group centers were below line of sight by a mean value of 19.38 cm (7.6 in). The nine rifle sample yielded a mean value of 4.88 cm (1.9 in) above line of sight for shot groups at 150 m range and a mean value of 17.01 cm (6.7 in) below line of sight for shot groups at 300 m.

Since averaging trajectory ordinates for the six rifle samples resulted in lower values, albeit statistically nonsignificant, than the theoretical ordinates at 150 m and 300 m, the data were also interpreted in terms of hit probability. This was accomplished by measuring the radial distance of the center of each bullet hole from the point of aim at 150 m, 250 m, and 300 m. Data for 250 m targets from Test 2 were also included. Figure 7 shows the distribution of the bullet distances by range. The distributions are similarly shaped for 150 and 250 m ranges, with the exception that 16% more bullets were at or exceeded 25 cm of displacement at 250 m than at 150 m. The distribution of bullet holes at 300 m is severely skewed to the left and shows 50% of bullet holes were at or beyond 25 cm from the point of aim.

TABLE 5

Mean Shot Group Size and Mean Vertical and Horizontal Displacement of Center of Shot Groups for Test 4

Sample Size	Range	Mean Shot Group Size	Mean Shot Group Displacement Vertical	Horizontal
	25m	2.83 (1.10)	+ .12 (.82)	- .45 (.52)
	150m	17.40 (8.04)	+ 4.87 (3.95)	+ 3.50 (7.30)
6	250m	32.50 (14.51)	- .53 (4.62)	- 1.13 (11.57)
	300m	31.07 (10.15)	-19.38 (9.97)	+ 1.15 (15.46)
	25m	3.02 (1.80)	+ .23 (1.40)	+ .62 (.93)
	25m	2.97 (1.13)	- .20 (.83)	- .26 (.60)
	150m	18.71 (7.12)	+ 4.88 (4.14)	+ 1.98 (6.22)
9	250m	31.17 (12.86)	- .99 (5.83)	- .48 (9.47)
	300m	30.67 (12.99)	-17.01 (8.95)	- 2.51 (13.61)
	25m	2.98 (1.45)	+ .14 (1.16)	+ .32 (1.10)

Note: All tabled values, except range, are in centimeters. Displacement below line of sight is denoted by -. Displacement left of line of sight is denoted by -. Numbers in parentheses are standard deviations.

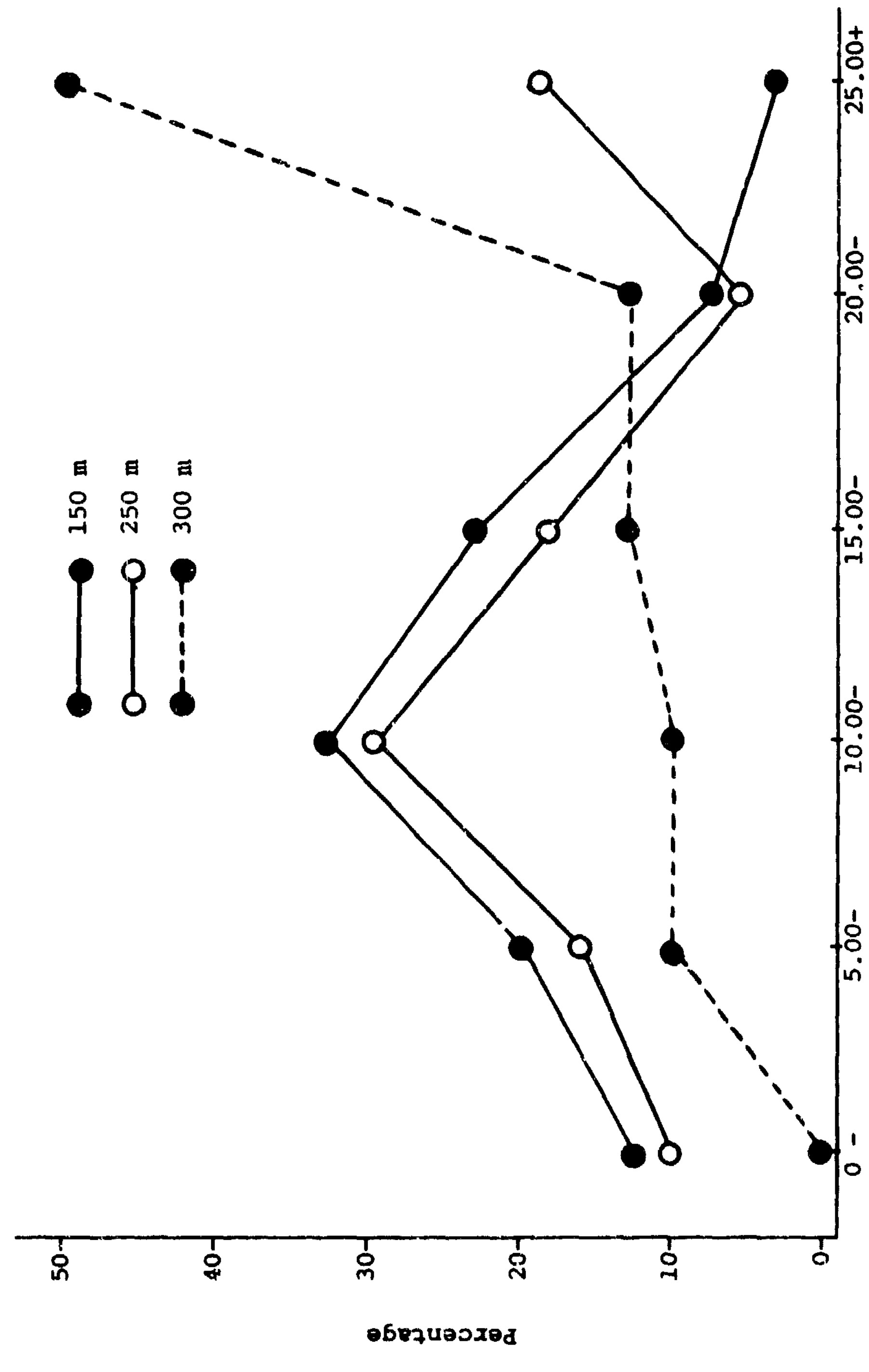


Figure 7: Distance (cm) from Point of Aim to Center of Bullet Hole

TABLE 6

Percentage of Bullets Off a Silhouette Target

and Percentages of Bullets Above and Below Point of Aim

Range	% of Bullets Off Target	% of Bullets Above Point of Aim	% of Bullets Below Point of Aim
150 m	0	72	28
250 m	5	50	50
300 m	21	7	93

These data were interpreted in terms of the percentage of bullets which would have hit an "E" type silhouette placed at the three ranges considered. These percentages are shown in Table 6 above. The ability of bullets to score a silhouette target hit was clearly reduced at 300 m; all misses were off the bottom of the target, low left, or low right, which is consistent with the finding that 93% of the bullets struck the lower half of the target at that range. In contrast, only 5% of bullets were silhouette target misses at 250 m. Bullet strikes, moreover, were equally split above and below point of aim. While no misses were scored for the 150 m range, 72% of the rounds struck above the point of aim. Both the position of shot groups and the number of hits at the three ranges are shown for some weapons in Figure 8.

Taken together, then, the trajectory data show that the average strike of the bullet is above point of aim at 150 m, but not significantly below the theoretical ordinate. The smaller obtained mean trajectory ordinate was not due to a large number of rounds hitting abnormally low. At 250 m the coincidence of point of aim and point of impact was consistent with an equal distribution of shots above and below the point of aim. At 300 m the majority of bullets were striking low, as expected, but on the average lower than the theoretical value for the ordinate. The variability of the shot group centers contributed to a finding that this displacement was not statistically significantly lower; however, 21% of the rounds would have missed an "E" type silhouette target had it been substituted for the pistol target.

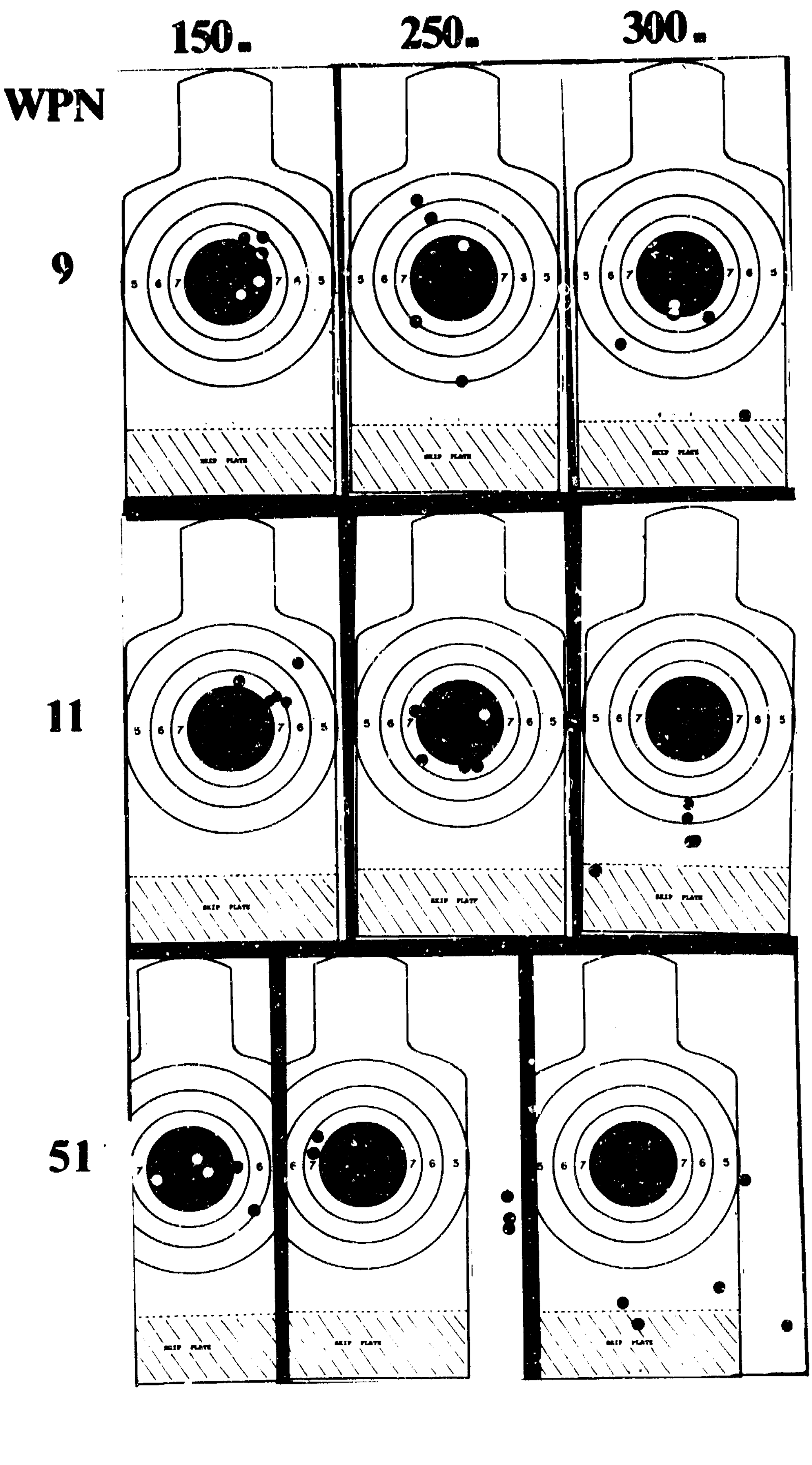


Figure 8: Trajectory Targets (Cradle). Bullet strikes at 150, 250, and 300 m for rifles zeroed for 250 m. Note that the bullets are generally high at 150, on at 250, and low at 300 m, and that Weapon 51 is totally erratic.

DISCUSSION

The results of Test 4 may be considered from two perspectives. As sample data from the population of M-16A1 rifles, the sample of six addresses the question of whether the rise and fall of the bullet trajectory as determined empirically coincides with the theoretical ordinates above and below the line of sight for the ranges examined. In this respect, the data generated in Test 4 did not evidence values so discrepant so as to challenge the theoretical values. One implication of the sampling process is that other samples of the same size could yield ordinate values coinciding with the theoretical values.

But the data may be considered from a practical point of view. That is, given that the six rifles were adequately zeroed, what is an aiming point rule-of-thumb for engaging targets at range? This question is related to the raw data provided in Appendix H. Of the five weapons firing low at 150 m, three also fired low at 300 m. The sixth weapon fired somewhat high at 150 m, but decidedly low at 300 m. Given Army training target sizes at 150 m and 300 m, a center of mass aiming point is adequate for 150 m. But at 300 m, a center of mass aiming point may yield a low probability of target hit because of bullets hitting low and off the target. For this sample, then, a higher than center of mass or shoulder hold might be the best choice of aiming point for 300 m targets. Given the variability of shot group placement at 300 m with this representative sample, a higher point of aim is indicated for all weapons.

TEST 5: RIMFIRE ADAPTERS

The objective of Test 5 was to compare the firing of service ammunition with the firing of .22 caliber long rifle ammunition utilizing the rimfire adapter.

PROCEDURE

Five rimfire adapters, obtained from the current version in use by the Basic Training Committee Group, Fort Jackson, South Carolina, were tested. Data were obtained with three procedures. The first was to randomly choose one rimfire adapter and place it in each of the six test weapons and three spares. The second procedure was to randomly choose rifles and rimfire adapters and fire from the cradle or a supported, hand-held position. Thirteen rifle/rimfire adapter combinations were fired, only three of which were from both the cradle and hand-held position. See Appendix J for the combinations tested. The third procedure was to fire all rimfire adapters through a Modified M-16 as described below. The same experienced individual fired all hand-held shot groups.

For the six cradle firings, the rifle was placed in the cradle and settled as in Test 2. Ten rounds were fired with 5.56 mm ball ammunition at an ARI target at 25 m. The weapon was loosened from the cradle, the standard bolt removed, and the rimfire adapter inserted. The cradle was retightened, a magazine containing .22 caliber long rifle ammunition fed into the weapon, and the weapon reaimed. A ten round shot group was then fired at an ARI 25 m target. Selection of weapon and rimfire adapter was randomized with replacement (i.e., a rifle or rimfire adapter could have been tested more than once).

Random selection with replacement was used to select seven combinations of rifles and rimfire adapters for hand-held firing. A ten round shot group was fired with 5.56 mm ammunition, followed by a shot group of ten .22 caliber rounds. In addition, the full sample of nine weapons was fired with the same rimfire adapter; ten rounds of .22 caliber and 5.56 mm ammunition were fired from each weapon. These data were obtained from a supported, hand-held position.

To provide a comparison of performance of standard rounds with rimfire rounds when precise aiming point could be assured, a Modified M-16 with a telescopic sight was employed. The Modified M-16 was obtained from the Army Marksmanship Unit and reportedly had been fired infrequently. Each rimfire adapter was used in the weapon to fire a ten round shot group. The zero of the weapon was confirmed with 20 rounds of 5.56 mm ammunition. A 10 round shot group was fired at the midpoint of, and one shot group at the conclusion of, the sequence of five rimfire adapter firings.

No attempt was made to zero the test weapons with the ball or .22 caliber ammunition. All .22 caliber ammunition used was manufactured by Remington (Lot No. C-28-E3).

RESULTS AND DISCUSSION

Regardless of the rifle/rimfire adapter combination or the manner in which the weapon was secured, the mean shot group size with rimfire adapters was considerably larger than with standard military ammunition. The statistical test of this difference is most appropriate for the data from the sample of nine weapons utilizing the same rimfire adapter (Hand-held--Full Sample). A t-test between mean shot group sizes resulted in a finding of statistically significant difference, $t = 2.82$, $df = 8$, one-tailed $p < .025$. For the other samples and the Modified M-16, the difference is consistently in the same direction as shown in Table 7.

Since an objective of the test was not to zero the weapons with each type of ammunition, exact evaluations of vertical and horizontal displacements are not considered. However, inspection of Table 7 shows that the variability of shot groups vertically was at least twice as large for .22 caliber rounds as it was for 5.56 mm rounds for the three test groups and the Modified M-16.

The results of this test of the rimfire adapter indicate that shot groups are larger and are more variable about their intended point of target impact than groups fired with standard Army ammunition. Moreover, shot groups of 5.56 mm ammunition generally did not overlap with shot groups fired with .22 caliber ammunition and rimfire adapter. As shown in Figure 11, a weapon judged to be zeroed with 5.56 mm ammunition might not be zeroed when fired with the rimfire adapter. If rounds are required to fall within a 4.0 cm circle during the zeroing process, the data indicate a relatively new weapon with reduced aiming error (Modified M-16) and most of the sample of nine test weapons would have difficulty meeting that criterion with .22 caliber ammunition.

These findings, together with the fact that frequent weapon malfunctions occurred with the rimfire adapter in place, indicate that for novice firers, the rimfire adapter is a source of increased weapon performance variability.

To allow the reader to appreciate more fully the apparent difference in performance and the variability with different rifle/rimfire combinations, several targets are presented in Figures 9, 10, and 11.

TABLE 7

Mean Shot Group Size and Mean Vertical and Horizontal Displacement of Center of Shot Groups Fired With 5.56 mm Ammunition and .22 Caliber Ammunition With the Rimfire Adapter

	Mean Shot Group Size		Mean Displacement			
			5.56 mm Ammunition		.22 Cal Ammunition	
	5.56 Ball	.22 Caliber w/ Rimfire Adapter	Vertical	Horizontal	Vertical	Horizontal
Hand Held (Full Sample)	M = 3.29 SD = .85 n = 9	M = 5.11 SD = 1.73 n = 9	M = +.13 SD = 1.16 n = 9	M = -.12 SD = .94 n = 9	M = +.74 SD = 2.39 n = 9	M = +.81 SD = 2.63 n = 9
Hand Held	M = 3.63 SD = 1.76 n = 6	M = 4.82 SD = .81 n = 6	M = -.16 SD = 1.58 n = 6	M = +.23 SD = .62 n = 6	M =+3.28 SD = 1.56 n = 6	M = +1.35 SD = 1.89 n = 6
Cradle	M = 3.67 SD = 1.37 n = 7	M = 5.11 SD = 2.06 n = 7	M = +.14 SD = 1.29 n = 7	M = -.01 SD = .84 n = 7	M = +.36 SD = 2.66 n = 7	M = +.91 SD = 3.08 n = 7
Mod. M-16	M = 3.25 SD = .05 n = 2	M = 5.36 SD = 1.07 n = 5	M = +.35 SD = .05 n = 2	M = -.20 SD = .00 n = 2	M =+1.42 SD = .54 n = 5	M = -.22 SD = .73 n = 5

Note: Means and standard deviations are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -.

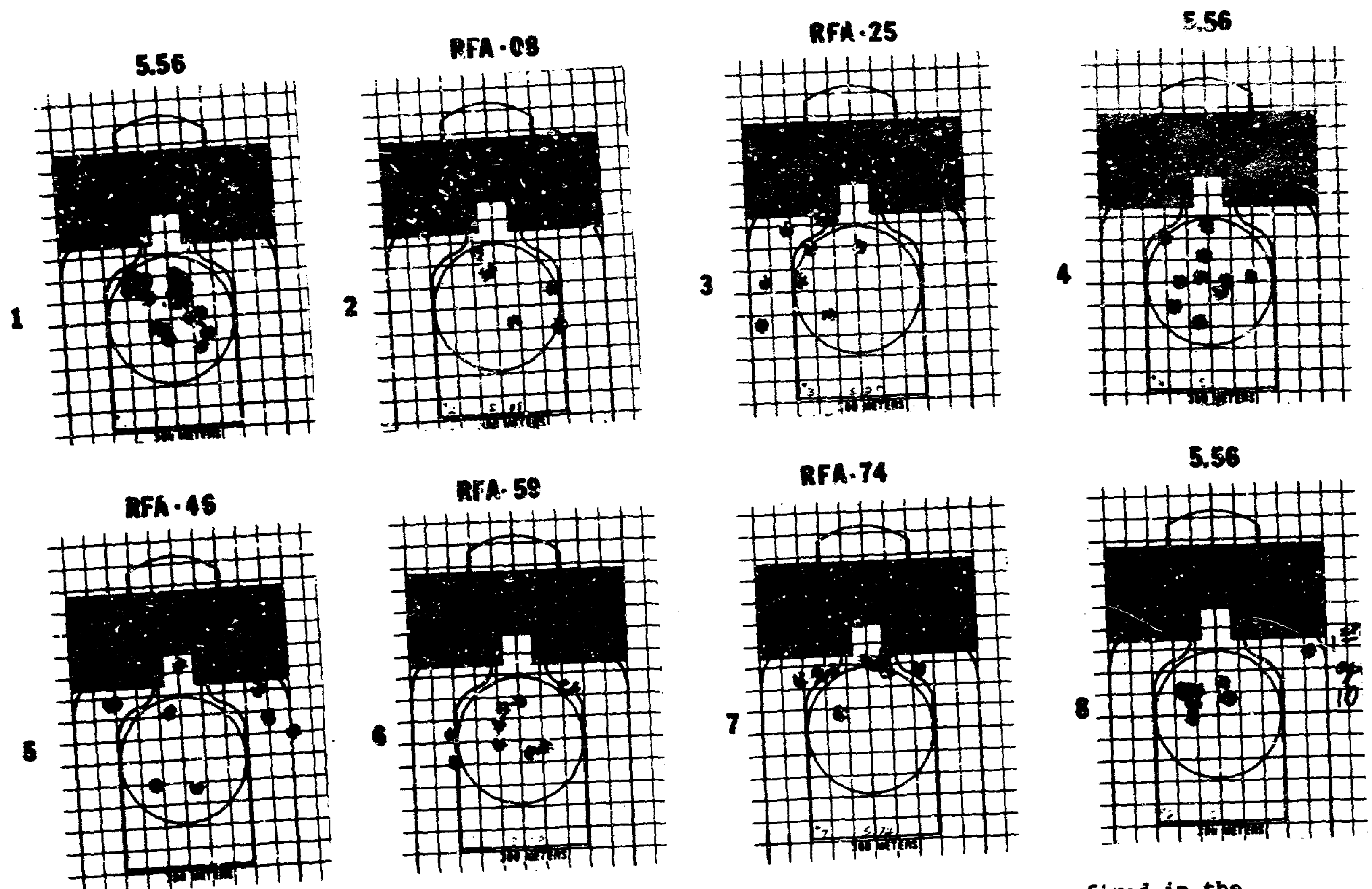


Figure 9: Five Rimfire Adapters (RFA) used in one weapon. Targets were fired in the sequence indicated, 20 rds in target #1 and 10 rds in targets 2 thru 8. Note the tendency for each rimfire to perform somewhat differently in this weapon. Of 50 caliber .22 rounds fired, about 25 were within the circle, while 39 of 40 5.56 rounds were within the 4 cm circle. The missing 5.56 round (see target #8) was the first 5.56 round fired after firing 30 caliber .22 rounds. Fouling from .22 rounds could have been a reason for this miss.

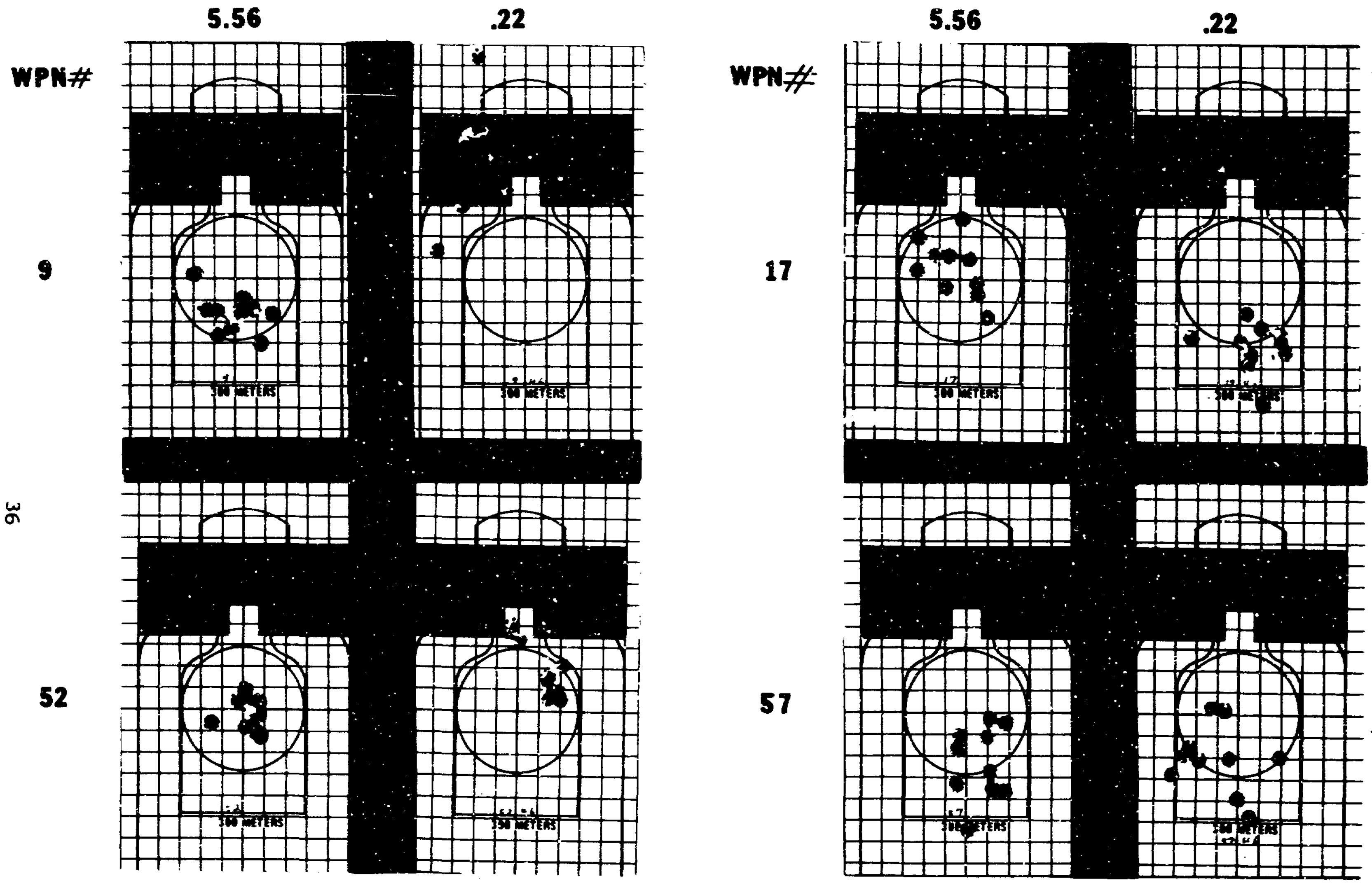


Figure 10: Rimfire Adapter (RFA) #46 used in several weapons (Hand held). Note the difference in performance as RFA 46 is used in different weapons - firing high in Weapon 9, low in Weapon 17, and firing consistently with 5.56 when used in Weapon 57.

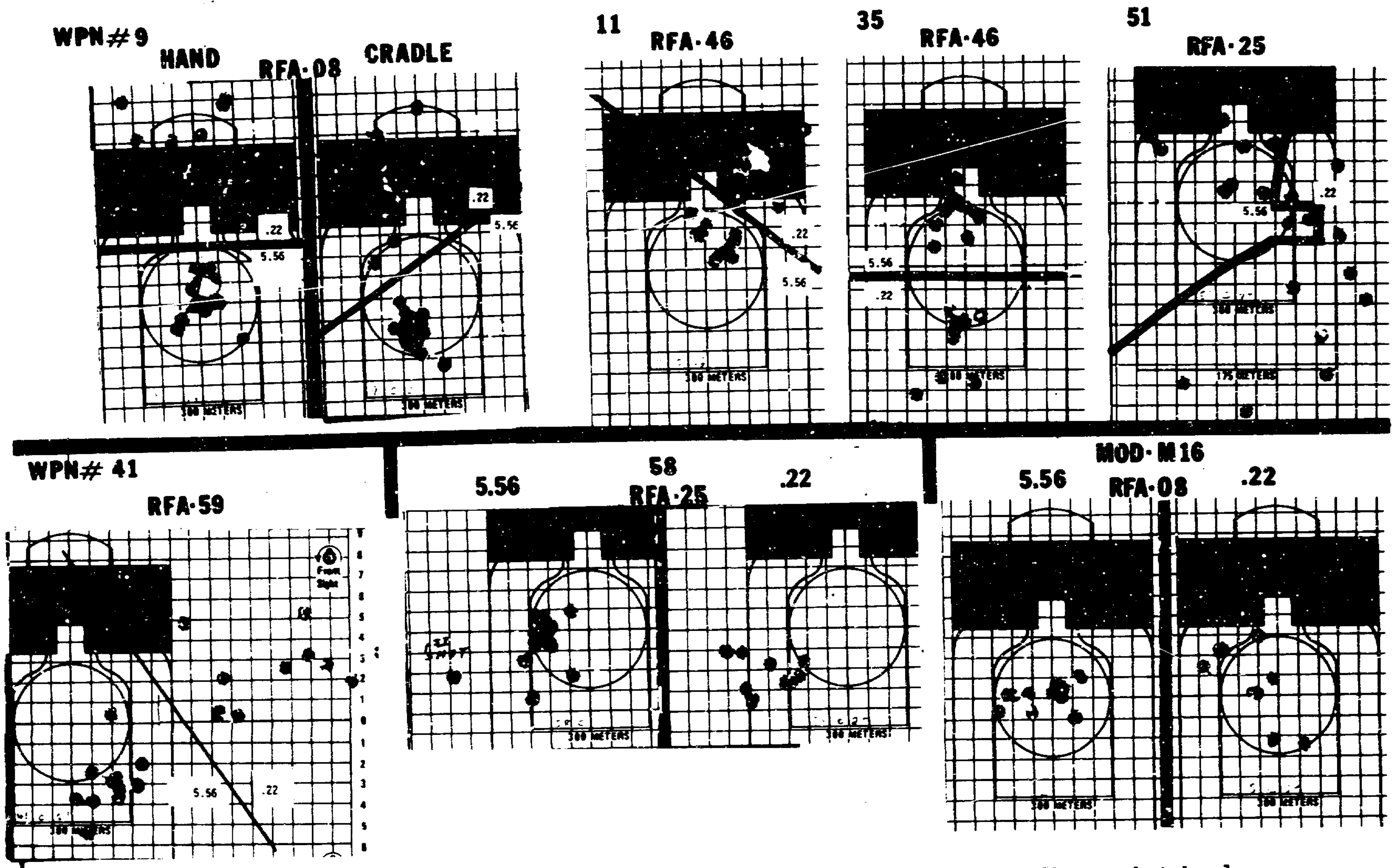


Figure 11: Rimfire Adapter Cradle Firings (except top left target which reflects that hand firings are similar to cradle firing results). Note that five of seven cradle firings are on the same target without bullet overlap. RFA 46 is high in Weapon 11 and low in Weapon 35. RFA 59, which was the best fit for the Modified M-16 (see Figure 9), appears to be a very bad fit for Weapon 41 (lower left target).

TEST 6: EFFECTS OF BARREL STRESS

The objective of Test 6 was to evaluate rifle performance with various sources of external stress placed on the weapon.

PROCEDURE

The six test weapons were fired at 25 m ARI targets by an experienced rifleman. All weapons were zeroed by the firer prior to the weapons being positioned with the following types of stress:

Hasty Sling. As prescribed in the United States Marine Corps FMFM 1-3, Basic Rifle Marksmanship, the web sling keeper was unfastened and moved to approximately 15 cm from the upper sling swivel. The sling was then loosened through the keeper. The sling was given a half twist and tightened as the left arm engaged the sling and the left hand supported the handguard.

Loop Sling. As prescribed in FMFM 1-3, the sling was unhooked from the rear sling swivel. The loose sling was fed through the buckle to form a loop. The loop was given a half turn, the firer inserted the left arm through the loop and positioned the loop on the left biceps. When necessary, the keeper at the muzzle end of the rifle was loosened and the sling tightened further. The left arm was placed over the sling and under the rifle so that the hand was under the handguard with the sling tightly securing the hand.

Bipod Support and Downward Pressure. A "clothespin" M3 bipod was attached to the barrel directly beneath the front sight between the bayonet lug and upper sling swivel. The butt of the rifle was placed on the right shoulder, and the left hand placed on the top of the handguard forward of the carrying handle. Moderate pressure was exerted downward on the handguard.

Bipod Supported Prone Position. The bipod and sling were used to control the weapon as described in the Army FM 23-9, M-16A1 Rifle and Rifle Marksmanship. The bipod was attached to the weapon as described above. The sling was loosened so that a loop could be formed at the upper sling swivel. The rifle butt was placed against the right shoulder. The left hand was placed in the loop, and moderate pressure exerted downward and to the rear.

Rearward Pressure on Front Handguard. The only exception to the customary support of the weapon was to exert moderate rearward pressure on the handguard with the left hand.

For four of the exercises, the firer sat at a table in an open area and placed the front support (bipod or left arm) of the weapon on the table. The rear of the rifle was placed against the right shoulder. The standard prone position was used for the bipod supported prone position. Five round shot groups were fired at ARI targets placed at 25 m.

RESULTS AND DISCUSSION

The objective of the test was to measure the amount of movement of rounds as a result of force applied to the rifle. The target coordinates of the center of the zero shot group for each weapon served as the reference point about which displacements of subsequent shot group centers were measured for that weapon. The size of the shot group and vertical and horizontal displacements of shot group centers about the reference point were determined in accordance with the procedure detailed in Test 2.

The results are summarized in Table 8. Without exception, the hasty sling and loop sling configurations resulted in considerable movement of rounds below weapon zero. Rearward and downward pressure to the sling from the bipod support and prone position evidenced less deflection downward of rounds, probably due to the horizontal component to the stress. Moderate rearward (horizontal) pressure to the handguard did not appear to result in a consistent effect in the vertical plane.

The expectation was that the forces applied to the rifle would affect rounds more in the vertical plane than the horizontal. This was borne out by the data, which indicate the magnitude of displacement (and the standard deviations) are of lesser magnitude for horizontal error. The data do indicate a bias of rounds to the right, perhaps due more to firer characteristics than to rifle characteristics. The effects of stress on the zero of the M-16 are shown in Figure 12.

This test clearly indicates that any form of stress placed on the forward portion of the rifle will have a major influence on the strike of the bullet. Therefore, all firing positions should be reviewed to insure that minimum stress is placed on the barrel during firing.

TABLE 8

Effects on Placement of Shot Groups of Six Sources of Stress to the Rifle

Source of Stress	Mean Displacement[a] Above	Below	Left	Right
Hasty Sling	n = 0	M = 5.10 SD = 1.99 n = 6	M = .53 SD = .25 n = 2	M = 1.48 SD = 1.40 n = 4
Loop Sling	n = 0	M = 3.25 SD = 1.67 n = 6	M = .40 SD = .06 n = 3	M = 1.11 SD = 1.00 n = 3
Bipod: Downward pressure	M = 4.65 SD = 2.77 n = 6	n = 0	M = .81 SD = .80 n = 4	M = 3.24 SD = .08 n = 2
Bipod: Prone/ sling	n = 0	M = 2.89 SD = 2.26 n = 6	M = 1.78 SD = .80 n = 4	M = 1.44 SD = .85 n = 2
Rearward pressure on front hand-guard	M = .67 SD = .28 n = 3	M = 1.32 SD = .37 n = 3	M = 1.22 SD = .59 n = 2	M = .58 SD = .38 n = 4

Note: All means and standard deviations are in centimeters.

[a] Displacement is measured from coordinates of center of zero shot group for each weapon.

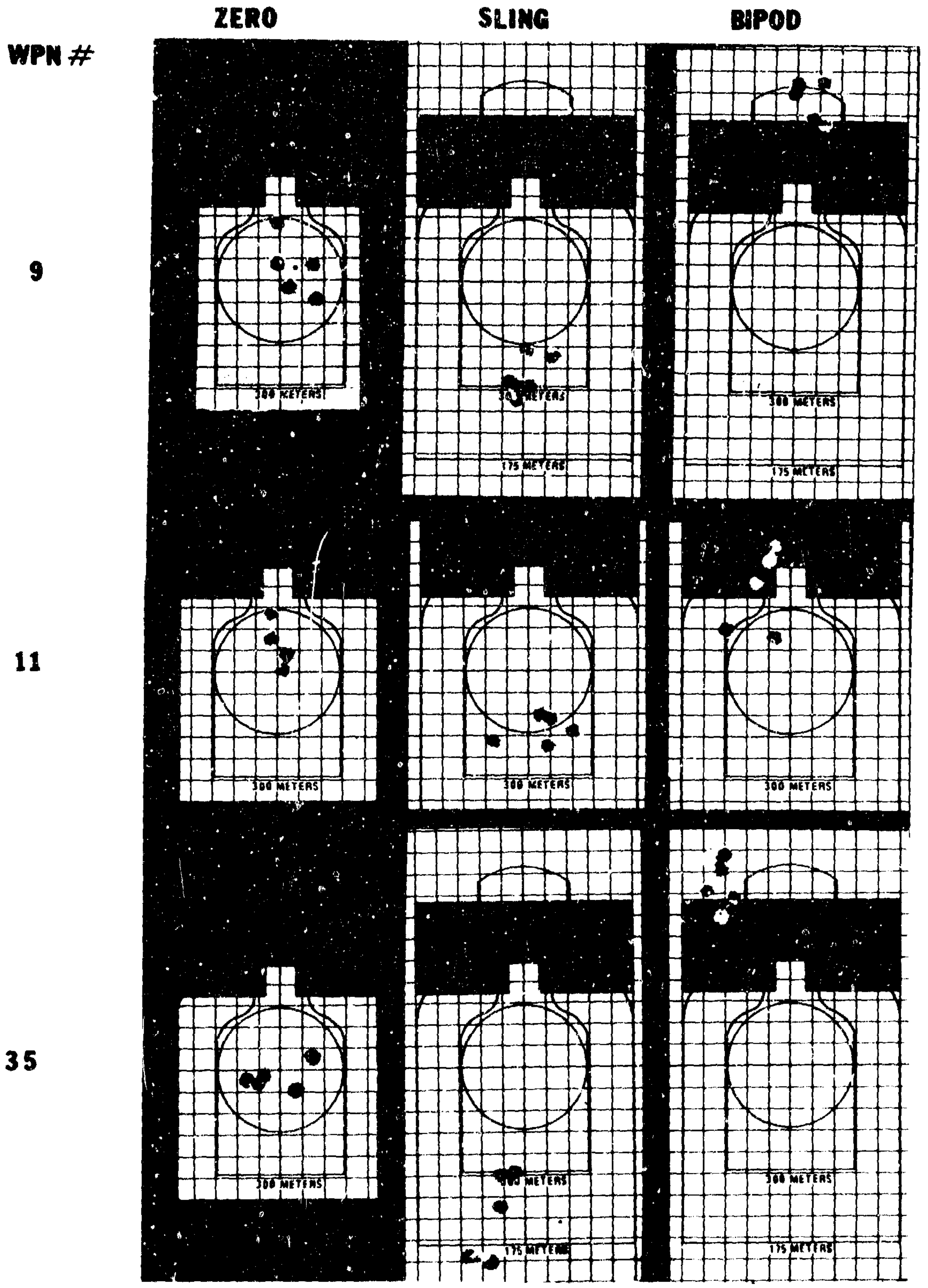


Figure 12: Rifle Stress (Hand held). The left targets show the normal zero, the center targets were fired with a <u>hasty sling</u>, and the targets at right were fired with a bipod attached and downward pressure applied with the left hand forward of the carrying handle. Note that the difference in bullet strike at 300 m would be two to four feet.

TEST 7: FIRER ERROR

The objective of Test 7 was to evaluate the effect of various types of firer errors on the placement of shot groups on 25 m targets.

PROCEDURE

The same experienced rifleman was enlisted to perform all the following procedures. The firings were accomplished in an open area with the firer sitting at a table. Two sandbags aided in supporting the front of the weapon. Single ARI targets were engaged at 25 m with shot groups of 5.56 mm ball ammunition. With the exception of the misalinement exercise, all six weapons were used in each of the following procedures:

Eye Relief.

- Eye Directly Behind Peep Sight. The firer's right eye was placed as close to the rear peep sight as possible (too close to be a practical stock weld).

- Nose Over Charging Handle. The charging handle was placed beneath the nose so that the rear of the handle was touching the upper lip.

- Tip of Nose on Charging Handle.

- Nose Behind Charging Handle. The tip of the firer's nose was placed 5 cm behind the charging handle.

- Face Halfway Between Peep Sight and Butt of the Weapon. This position was regarded as defining the maximum placement of the head behind the peep sight (too far back to be a practical stock weld).

Cant Left. The weapon was positioned so that the angle between the front sight post and the vertical was between 25 and 30°. The weapon was tilted to the left from the firer's perspective.

Cant Right. The weapon was tilted to the firer's right so that the angle between the front sight post and the vertical was in the range of 25 to 30°.

Breathing, Jerking, and Flinching. The firer was instructed to breath during aiming and firing, anticipate the discharge of the round, and pull the trigger with an abrupt movement.

Misalinement. This exercise was conducted with weapon numbers 9 and 35 placed in the cradle. The weapons test expert and an experienced firer misalined the front and rear sight so that (a) the front sight post appeared to be placed one-quarter of the distance from center toward the 12, 3, 6, and 9 o'clock points of the peep sight aperture (i.e., minimal misalinement) and (b) the front sight post was moved from center toward the 12, 3, 6, and 9 o'clock points of the peep sight aperture to the degree that it virtually disappeared from view (maximal misalinement).

RESULTS

The first five procedures introduced various degrees of eye relief, most of which were exaggerations of the eye relief differences likely to occur with the M-16A1. Targets from each of the five positions fired by three weapons are presented in Figure 13 and the data are presented in Table 9. Since the movement of the eye from the peep sight towards the butt did not occur in equal increments, the data are not amenable to statistical analysis to reveal reliable trends. Since the shot group sizes of Weapon 51 were markedly larger for Test 7 than those of earlier tests, summary statistics of the rifle sample minus the Weapon 51 data are presented in Table 9. For the purpose of comparisons, shot group sizes of the full six rifle sample are also included.

Using the data from the exercise with the tip of the nose on the charging handle as the standard, mean shot group size was not adversely affected in any of the other four positions. Comparisons of data from these other positions to the standard exercise revealed no systematic variation in horizontal or vertical placement of centers of shot groups. Aside from some variability in the size and position of shot groups introduced by the awkwardness of some firing positions, progressive changes of eye relief did not result in a deterioration of performance.

Canting the weapon to the left resulted in a small increase in shot group size when contrasted to the standard firing position, but a slight decrease for cant right. Sample targets are shown at Figure 14.

The severe tilt of the weapon was expected to move rounds in the direction opposite the tilt. When the horizontal displacements were adjusted for horizontal displacement obtained with the standard firing position, the mean displacement with cant left was .98 cm towards the right and with cant right .90 cm to the left. The data reveal displacement was generally limited to a fraction over one click error with abnormally severe tilts of the weapon. Vertical displacement was below

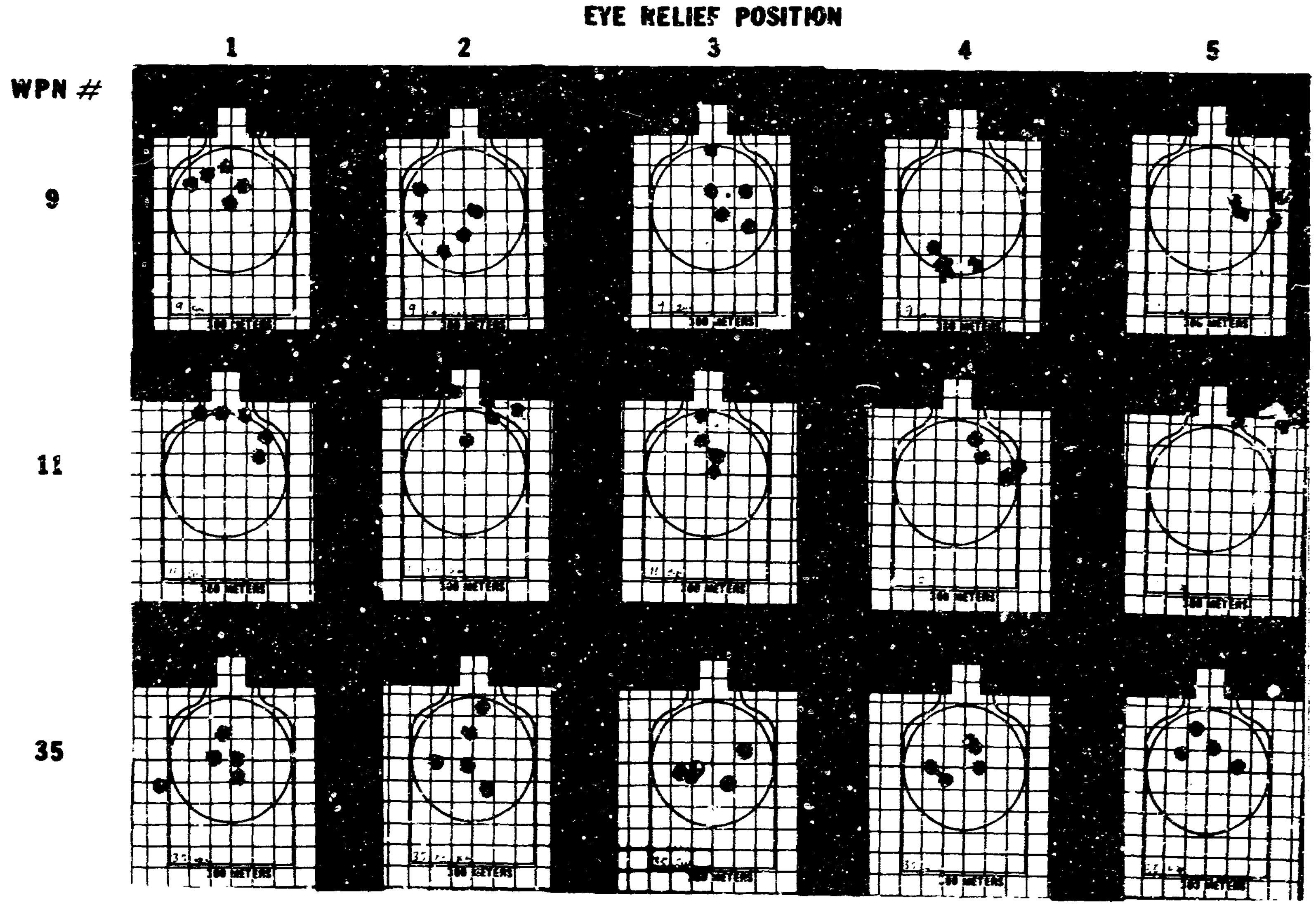


Figure 13: Eye Relief (Hand held). Five different eye relief positions: #1 - Eye as close to peep as possible, #2 - Charging handle pressed against upper lip, #3 - Tip of nose on charging handle, #4 - Nose 5 cm behind charging handle, and #5 - Face halfway back on stock.

TABLE 9

Mean Shot Group Size and Mean Vertical and Horizontal Displacement of Shot Group Centers with Various Firer Errors

Firer Error	Six Rifle Shot Group Size	Five Rifle Shot Group Size[1]	Mean Shot Group Displacement[1] Vertical	Horizontal
Eye directly behind peep sight	M = 3.38 SD = 2.16	M = 2.56 SD = .85	M = + .82 SD = .58	M = -1.52 SD = 3.49
Nose over charging handle	M = 4.48 SD = 3.69	M = 2.88 SD = 1.05	M = + .80 SD = .95	M = + .22 SD = .78
Tip of nose on charging handle	M = 3.27 SD = 1.15	M = 3.14 SD = 1.39	M = + .63 SD = .58	M = + .15 SD = .72
Nose 5 cm behind charging handle	M = 2.53 SD = .92	M = 2.24 SD = .80	M = - .22 SD = .94	M = + .25 SD = .73
Face halfway back on stock	M = 4.20 SD = 3.35	M = 2.74 SD = .91	M = + .79 SD = 1.08	M = +1.44 SD = .84
Cant left	M = 4.22 SD = 2.12	M = 3.24 SD = .39	M = - .01 SD = .80	M = +1.13 SD = .38
Cant right	M = 4.05 SD = 2.81	M = 2.80 SD = .28	M = - .03 SD = .89	M = - .75 SD = .90
Breathing, jerking, and flinching	M = 8.83 SD = 5.46	M = 6.56 SD = 2.07	M = - .01 SD = 1.92	M = - .11 SD = .64

Note. All tabled values are in centimeters. Displacement below center of zeroing circle is denoted by -. Displacement left of center of zeroing circle is denoted by -.

[1]Six rifle sample with Weapon 51 data removed.

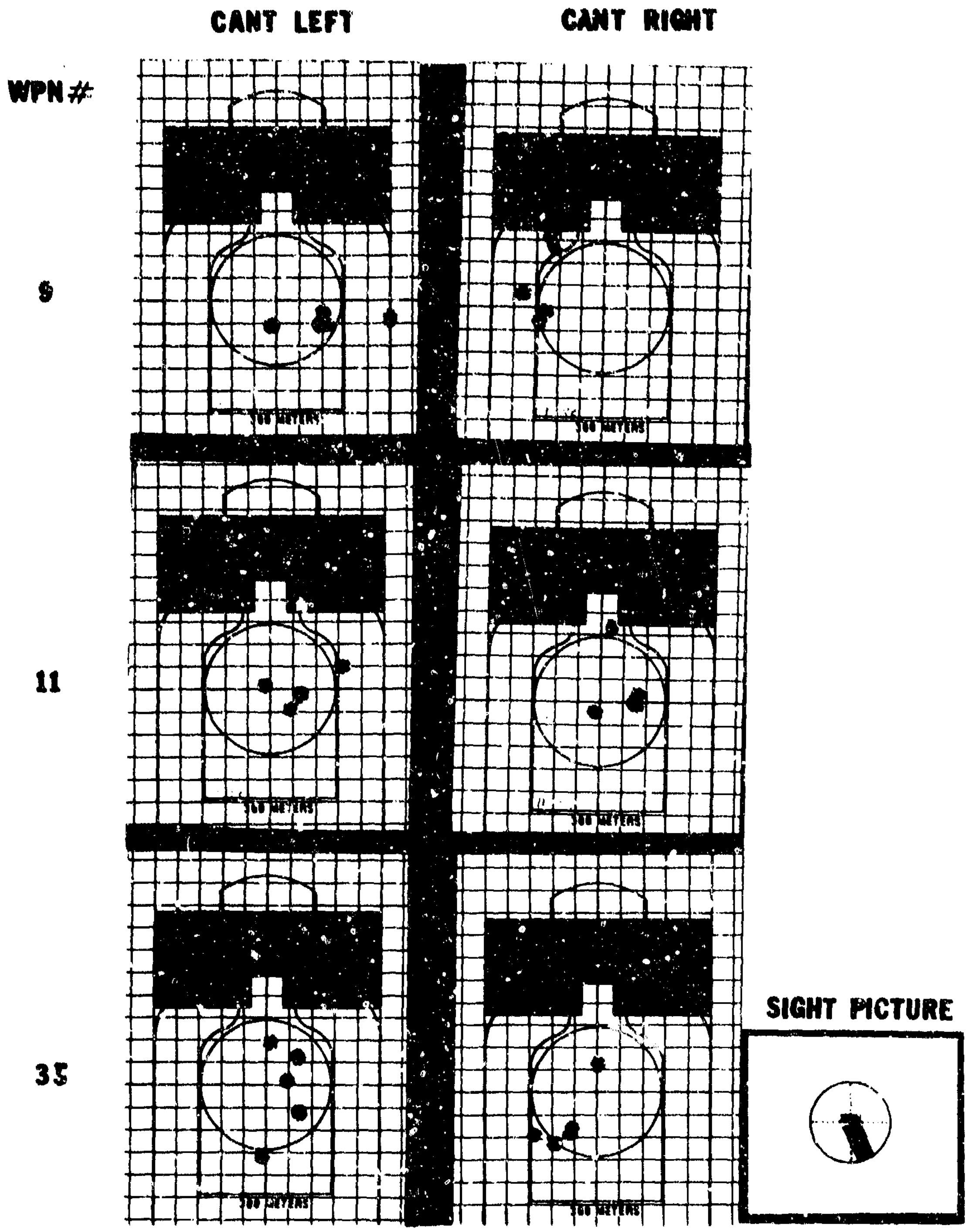


Figure 14: Cant Left and Right (Hand held). The above sight picture reflects the severe cant of the weapon for these firings. The sight picture shown is for cant left.

that of the standard position for both cant left and right in amounts equivalent to one click.

Table 10 contains the data obtained from Weapons 9 and 35 under conditions of minimal and maximal misalinement of the front and rear sights. The targets from these firings are shown at Figure 15. The effects of misalinement of the front sight post from center towards the upper and lower extremes of the rear sight aperture were expected to be reflected vertically in the placement of shot groups. The shot groups placement was adjusted on the basis of the coordinates of the zero of each weapon fired with normal sight alinement. The results indicated approximately 1 cm of movement above zero when the front sight was moved upward one-quarter of the aperture center-to-edge distance. Likewise, 1 cm of displacement downward of the shot group center resulted from lowering the front sight post one-quarter of the aperture center-to-edge distance.

The vertical displacements of the shot groups increased as the front sight post was moved up or down in the aperture field to the maximum extent. The observers reported that the sight post nearly disappeared from sight in this condition. The effect of shot group placement (zero adjusted) was on the order of 1.9 cm for upward misalinement and 4.8 cm for downward misalinement. The reason for this large difference in shot group displacement between upward and downward misalinement is not known.

One-quarter lateral movement to the left of the front sight shifted the shot groups left by approximately 1 cm, as contrasted to less than one-half that amount of right displacement for front sight movement to the right. Maximal misalinement left and right resulted in 4.6 cm left displacement and 5.8 cm right displacement, respectively, of shot group centers.

The misalinement data indicate a small movement off center of the front sight post yields shot group misplacement on 25 m targets generally in the range of 1 to 2 clicks. Maximal misalinement increases the displacement to the range of 6 to 9 clicks. It is unlikely that even a novice firer would misaline sights much more than the one-quarter error used in the test, because part of the aperture begins to darken when more error than this is made.

Finally, the results of introduced breathing, flinching, and jerking the trigger are most apparent in the effects of shot group size. Not only did mean shot group size increase by a factor of 2, but variability in shot group size also increased when compared to the shot group fired from the conventional, well-controlled position.

TABLE 10

Effects of Minimal and Maximal Sight Misalinement on Shot Group Placement at 25 meters

Direction of Misalinement	Rifle	Magnitude of Effect of Minimal Misalinement of Sights[a] Vertical	Magnitude of Effect of Minimal Misalinement of Sights[a] Horizontal	Magnitude of Effect of Maximal Misalinement of Sights[a] Vertical	Magnitude of Effect of Maximal Misalinement of Sights[a] Horizontal
Up	9	+ .90	- .63	+1.43	- .68
	35	+1.42	- .40	+2.42	+ .33
Down	9	-1.10	- .34	-4.30	+ .59
	35	-1.18	- .20	-3.22	+ .83
Left	9	- .07	-1.37	-1.97	-5.31
	35	+ .31	- .84	-2.12	-3.93
Right	9	+ .33	+ .23	+3.57	+4.99
	35	+1.31	+ .50	- .38	+6.63

Note. All tabled values, except rifle number, are centimeters.

[a]Displacement of center of shot group from zero (no misalinement) for each rifle. Displacement below zero is denoted by -. Displacment left of zero is denoted by -.

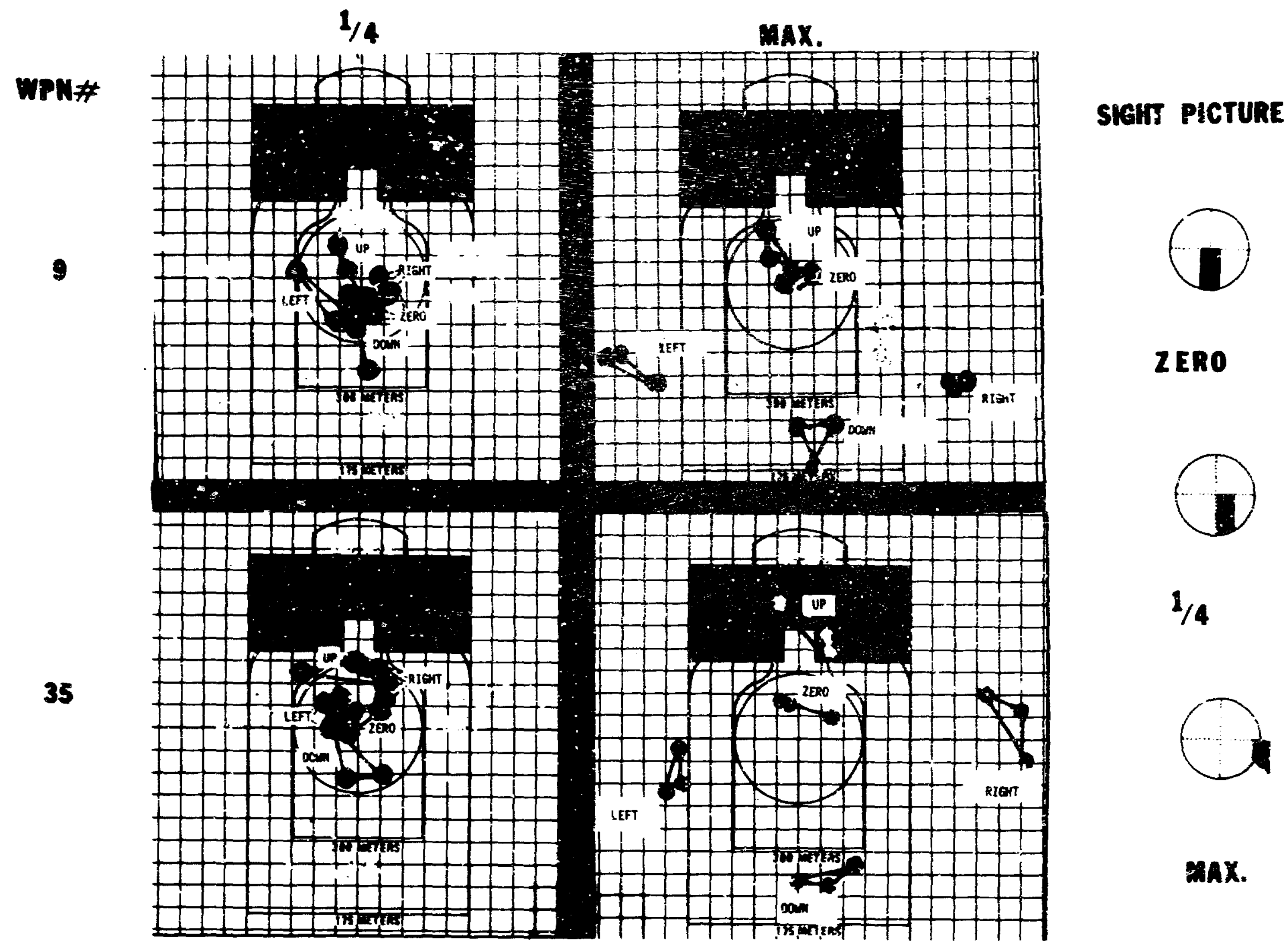


Figure 15: Sight Alinement (Cradle). The sight pictures reflect the amount of alinement error made in each of four directions. Each target has 15 hits, three for zero and three in each of four directions. The one-quarter misalinement targets have several overlapping shots; however, each misalined shot group has two rounds in the intended direction from the center of the zero shot group.

DISCUSSION

The importance of obtaining the same eye relief for the firing of each round receives emphasis during basic marksmanship training. Given the absence of any mathematical computations that determine the expected differences in placement of shots as a result of different degrees of eye relief, the six weapons were fired with five different eye reliefs to determine if an obvious and predictable pattern would emerge. A review of the top row of targets of Figure 13 appears to indicate that a definite pattern is being established for the different eye relief positions; however, subsequent firings failed to support any uniform variability that can be related to eye relief. The increased shot group size and outlying shots could have been caused by the unfamiliar firing position. Therefore, given the normal variability in shot group placement expected as different targets are engaged and the extreme difference in the five eye relief positions used, eye relief does not appear to be a factor that has major influence on the placement of bullets. It appears reasonable to conclude that obtaining exactly the same degree of eye relief should not be a primary requirement of marksmanship fundamentals training.

Canting the rifle while firing did move the strike of the bullet in the expected direction. However, the relatively small movement resulting from severe cant indicates that normal weapon cant would not be a major degradation to accurate shooting. This conclusion is illustrated by referring to the targets reproduced in Figure 14. As is the case with differences in eye relief, trainers need not emphasize that the rifle be maintained in a perfectly vertical orientation until more basic fundamentals are mastered.

Correct sight alinement probably receives more emphasis than any other factor during basic marksmanship instruction. The sight alinement portion of this firing test was conducted because theoretical computations indicate that sight alinement error should affect bullet strike much less than most charts and sketches indicate. The Army Shot Group Analysis Card (GTA 21-1-4) contained in Chapter 3 of FM 23-9, M-16A1 Rifles and Rifle Marksmanship, uses a sketch that indicates one-quarter misalinement of sights will result in missing the center of a silhouette target at 300 m by 50 in. Given the sight picture depicted on the analysis card, a simple computation shows that the bullet should miss target center by only 6 in, which nevertheless is a hit at 300 m.

The sight alinement test results give a strong indication that, with one-quarter sight misalinement, the error at 300 m may well be less than the value of 6 in. The largest errors of shot group placement at 25 m, under conditions of minimal sight misalinement (see Table 10), multiplied by a factor of 12 (300 m divided by 25 m), yields an expected error of 6 in at 300 m. But most errors at 25 m were considerably smaller with an average of .38 cm. This computes to an expected error of 1.8 in (4.56 cm) at 300 m. The misalinement data, therefore, provides clear empirical justification for questioning the validity of the sight alinement information portrayed on the shot group analysis card. A further implication is that sight misalinement may be less of a source of firer error than currently perceived by trainers.

The intent of the latter portion of this test, reported as breathing, jerking, and flinching, was to introduce various errors into the firing process that would result in the creation of shot groups depicted on the shot group analysis card. As discussed above, the sight alinement errors depicted are not valid. The point of aim errors were easy to represent in shot groups, except straight lines (as depicted on the shot group analysis card) could not be created for vertical or horizontal groups. Breathing errors alone could not be created without an obvious violation of aiming point, trigger control, or both. Since most shot groups could not be created in preliminary firings, and since these firings did not yield a productive outline for the introduction and objective evaluation of various errors in the firing process, all weapons were fired with instruction given to the firer not to control breathing, to jerk the trigger, and flinch with the firing of each round. No discernable pattern was established.

The fact that the errors shown on the shot group analysis card could not be created by a deliberate effort of the firer has a serious implication. If a direct cause-effect relationship can not be demonstrated between a suspected firer error and the resultant shot group configuration, than the use of the shot group analysis card for diagnostic purposes is of questionable value. Further research is indicated to investigate whether the concept of shot group analysis is useful for diagnostic purposes.

TEST 8: TRAINEE FIRINGS

The objective of Test 8 was to evaluate the effects of trigger pull and target type on the firing performance of trainees.

PROCEDURE

Ten trainees were detailed for the purpose of this test from an Infantry AIT Company at Fort Benning, Georgia. The trainees had completed their basic rifle marksmanship training with the following marksmanship qualifications: two were experts, three sharpshooters, and five marksmen. Target firing was accomplished on a 25 m zeroing range with the trainees firing from a foxhole, supported position. The trainees engaged both an ARI target and the scaled silhouette target (Appendix G) with three rounds from each weapon. Order of firing constituted a Latin square design, but the data were incomplete due to a weapon malfunction which could not be repaired on site. Silhouette targets were engaged with the long range sight rotated into view. The trainees were instructed to engage the silhouettes by aiming center of mass and to use the Canadian bull in the conventional manner.

RESULTS

Mean shot group size was 3.55 cm on ARI targets and 3.60 cm on the silhouette targets. Neither this difference ($t < 1$) nor the correlation between shot group sizes ($r = -.22$) was statistically significant at the .05 level. The statistics report comparisons made among mean shot group sizes collapsed across weapons for each firer. These results indicate that the trainees, as a group, fired equally well at each target type. Individually, however, some trainees fired tighter shot groups at the ARI target and others at the silhouette target.

Since the weapons were approximately zeroed from previous tests and were not individually zeroed by each trainee, mean horizontal and vertical displacements across weapons and trainees are not meaningful statistics. However, using the same anticipated point of impact on the two targets as established for Test 3, potential differences in the placement of shot groups on each target could be evaluated (assuming firers biases are consistent).

The trainees evidenced considerable consistency in vertical placement of the center of shot groups as revealed by a significant positive correlation, $r = +.57$, one-tailed $p < .05$. Only under the condition that the trainees had been aiming much higher than center of mass would the correlation have been negative; that the correlation was positive and of moderate magnitude indicates the trainees aiming point on the silhouette target was approximately the center of mass used in scoring. The correlation of horizontal displacements was somewhat larger, $r = +.81$, one-tailed $p < .005$, indicating less sighting error in the left-right dimension. This is to be expected since the edge of the silhouette target offers a definite reference point for horizontal adjustments of aiming point. Therefore, the consistent placement of shots leads to the conclusion that the long range sight/silhouette target combination does not adversely affect the firing performance of relatively inexperienced firers.

The data also revealed that trigger pull was not related to performance as measured by mean shot group size. The correlation between mean shot group size per weapon (averaged across trainees) and trigger pull was $r = .07$, $p > .05$ (ARI target) and $r = .03$, $p > .05$ (silhouette target). Inexperienced firers, therefore, were not influenced by differences in trigger pull of the sample of weapons. In other words, the resistance of the trigger per se is not related to performance differences with relatively inexperienced firers when firing from foxhole supported positions.

DISCUSSION

The results of this test address questions raised in Tests 1 and 3. In Test 1, trigger pull was found not to correlate with shot group size; Test 3 demonstrated the feasibility of obtaining a 250 m BSZ with the scaled silhouette/long range sight combination at 25 m. In both these tests, experienced riflemen fired the weapons. If the results of these tests are to be used in marksmanship training program development, then the results should be validated by firers from the trainee population. The critical consideration is whether experienced riflemen compensated for variations in trigger pull and experienced less ambiguity in establishing an aiming point on a scaled silhouette. By examining these possibilities with trainees, the expert firer/inexperienced firer dichotomy was demonstrated to be unrelated to the two variables under consideration. Moreover, the scaled silhouette/long range sight finding attains validity in having been obtained with a sample from the population that might receive this alternative zeroing procedure.

TEST 9: SHOOTING QUALITY AND MAINTENANCE

The objective of Test 9 was to consolidate findings from foregoing tests to address questions of rifle shooting quality and maintenance.

PROCEDURE AND RESULTS

The data on shot group size at 25 m obtained in cradle firing during Tests 1 through 4 were plotted in Figure 16. The figure presents data on each of the six test weapons and reveals that three of the weapons fired remarkably consistently across the four tests. Of the remaining three weapons, Rifle 58 fired progressively larger shot groups, Rifle 41 fired large groups on one test day, and Rifle 51 fired a sawtooth pattern oscillating about 4.0 cm. The overall means and standard deviations of shot groups of this data are listed in Table 11. The pattern depicted in Figure 5 is revealed most clearly in the standard deviations which are three or four times larger for Rifles 41, 51, and 58, than for Rifles 9, 11, and 35. The Pearson correlation between the mean and standard deviation is $\underline{r} = .92$, two-tailed $\underline{p} < .01$, indicating a rifle firing larger groups will evidence more variability in shot group size from group to group.

TABLE 11

Means and Standard Deviations

of 25 m Shot Group Size for Tests 1 Through 4

Rifle Number	Mean Shot Group Size	Standard Deviation of Shot Group Size
9	2.26	.64
11	1.79	.46
35	2.09	.39
41	2.96	1.60
51	5.62	2.22
58	3.14	1.41

Note: Means and standard deviations are in centimeters.

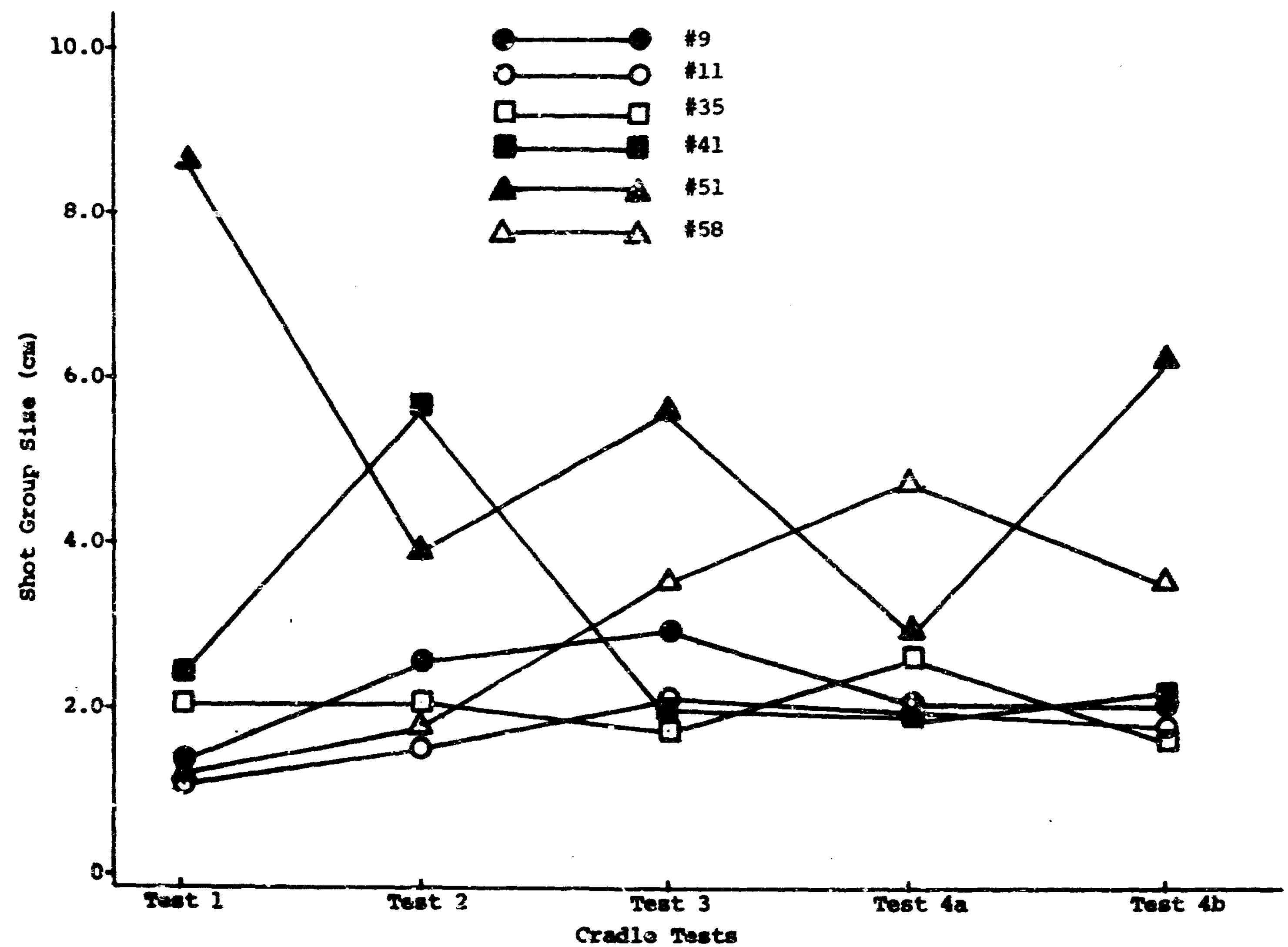


Figure 16: Mean cradle shot group sizes of six test weapons for Tests 1 through 4.

These findings can be used to provide an answer to a problem encountered during Test 1: that is, what physical measurement or firing characteristic obtained from a rifle identifies that weapon as a good or bad weapon? Recall that no standard mechanical measurement differentiated rifles in Test 1. However, the initial cradle shot group fired in Test 1 might be enlisted to predict cradle firing performance over some future period. This possibility was examined by using the method of least squares to obtain a function relating initial shot group size (x) to the mean of later shot group sizes (y) observed in Tests 2 through 4. The straight line functions are shown in Figure 17. Since the data are linearly related, correlation coefficients were computed. Initial shot group size correlated positively with mean shot group size, $\underline{r}$ · .84, one-tailed $\underline{p} < .025$, but initial shot group size did not correlate with the standard deviation of shot group size ($\underline{r} = .53$, $\underline{p} > .05$). Since the test of significance for a zero order correlation is equivalent to the test of the slope of the best fit linear function, the conclusions are that (a) there is a positive relationship between initial shot group size and later shot group size, and (b) in principle, initial shot group size can be used as a predictor of shot group size, but not the variability of shot group size, obtained later in time.

These findings do not mean that the specific function obtained for these data can be applied to predict performance of any one or group of M-16A1 rifles. To illustrate this point, the function obtained for the cradle firings was compared to the function derived for the two experienced firers. The correlation coefficients, slope, and intercepts are listed in Table 12. Note that Firer 1 showed firing performance very

TABLE 12

Correlation Coefficients and Slopes and Intercepts

of Regression Equations for Cradle and Experienced Firer Data

Firer	Correlation Coefficient[1]	Regression Equation Slope	Regression Equation Intercept
Cradle	.84*	.309	2.099
Firer 1	.82*	.371	1.590
Firer 2	.95**	1.623	-2.210

[1] **Correlation between initial shot group size and mean of subsequent shot group size.**

* $\underline{p} < .025$, one tailed test ** $\underline{p} < .005$, one-tailed test

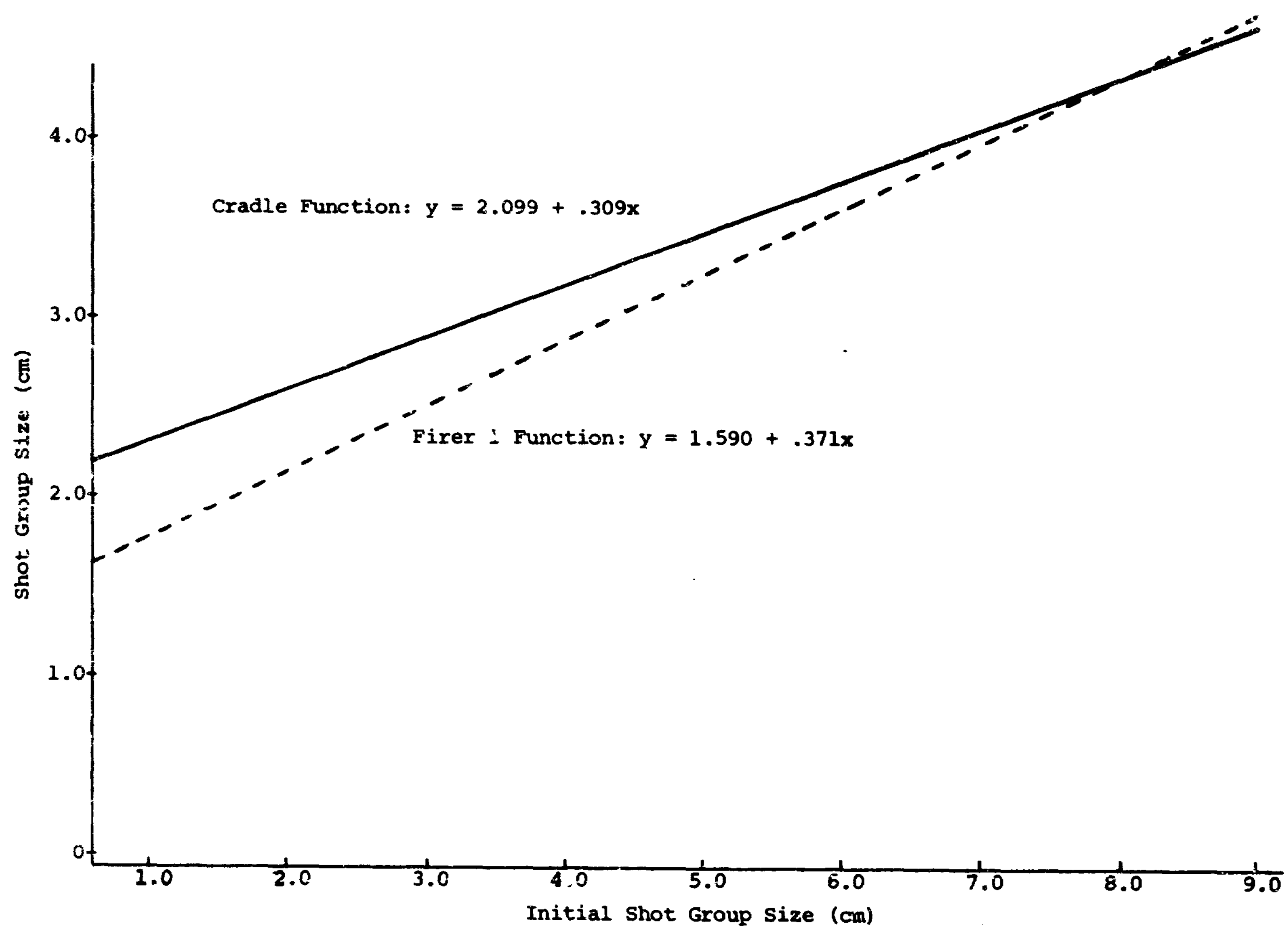


Figure 17: Prediction functions of subsequent 25 m shot group size from initial 25 m shot group size. Ordinate value for cradle function is the mean shot group size for Tests 2 through 4 and for Firer 1 is the mean of Test 3 shot group size.

similar to the cradle; the other firer fired much larger shot groups, and therefore, his prediction function is much steeper. The key point is that, in all three cases, a high degree of prediction accuracy is demonstrated. The data in Table 12 demonstrate that a single prediction function is not obtained. More importantly, regardless of individual firer characteristics. it is possible to predict later shot group size of a rifle from initial shot group size.

To observe variation in rifle performance due to ammunition characteristics was not part of the initial test plan. But during the early phase of testing, a total of 65 Federal, .223 Remington, 55 grain soft point rounds were fired from the test weapons. Shot group size was measured in the same way as for military ammunition. Table 13 shows the results of this comparison of commercial ammunition and military ammunition fired during the same period of time. Sample targets are included in Figure 18. Although the small sample size and unsystematic test procedure preclude statistical analysis, the decrease in shot group size and variability with commercial ammunition is impressive at all target ranges sampled. The results with the Modified M-16 rifle are paradoxical in that no improvement or an increase in shot group size with the commercial ammunition was obtained. But for the remainder of the weapons sample, the shot group size decreased. Most dramatic is the five-fold decrease of shot group size for Weapon 51, which was the poorest performing weapon obtained in the original sample of 60 weapons.

A comparison of the military (Lot LC-2-421) and commercial ammunition (Lot 15A-8234) indicated that the variance in powder weight was about the same, the commercial ammunition had somewhat less variance in bullet weight - .4 grains compared to .6 grains for the military, and the variance in bullet diameter was about the same - .0002 for the commercial and .0003 for the military; however, some of the difference in performance may be accounted for by the relatively larger diameter of the commercial ammunition - .2247 compared to .2241 for the military. The muzzle velocity of the commercial ammunition was approximately 100 feet per second less than the military ammunition.

Replacing the standard ball in the military ammunition with .224 diameter 52 grain hollowpoint boattail Sierra bullets did not make a significant difference in performance.

Maintenance was not a formal part of the test, but accurate records were maintained on weapon failures and major malfunctions. The following

TABLE 13

Shot Group Sizes with Standard Military 5.56 mm

Ammunition and Commercial .223 cal Ammunition

Range	Rifle	Shot Group Size: Military Ammunition	Shot Group Size: Commercial Ammunition
25 m	51	M = 10.20	M = 2.60
		SD = 1.23	SD = .50
		n = 3	n = 3
25 m	Other*	M = 3.23	M = 1.63
		SD = .78	SD = .66
		n = 3	n = 3
100 m	9	13.50	4.40
	11	17.50	12.00
	35	6.60	5.80
	Mod M16	4.80	13.00
125 m	11	9.80	5.20
	35	16.00	5.20
	Mod M16	6.00	6.00

* Weapons from the initial sample of 59 which were not included in subsequent tests.

Note: All tabled values, except range are in centimeters.

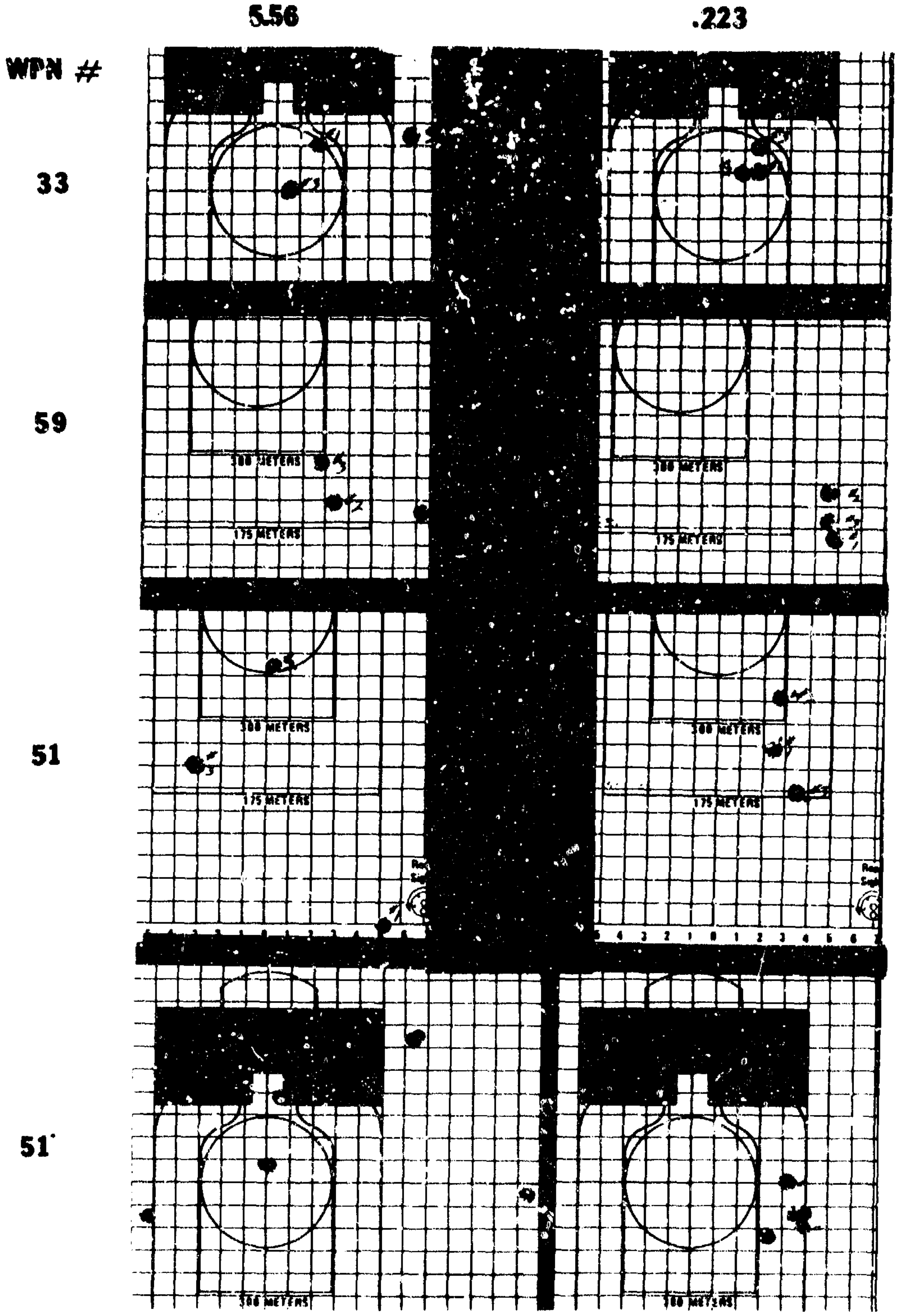


Figure 18: Commercial Ammunition (cradle, top three - bottom targets hand held*). Most weapons showed a marked improvement in performance when ammunition purchased from the local Post Exchange was used.

direct/general support maintenance deficiencies were observed from the sample of 60 weapons:

Weak hammer spring - 1 weapon

Trigger pin bent - 1 weapon

Rear sight spring missing - 2 weapons

The following malfunctions occurred while firing eight rounds through each of the 60 weapons:

Double feed - 1 weapon

Failure to feed 1 round - 5 weapons

Failure to feed 3 or more rounds - 2 weapons

Failure to extract 8 rounds - 1 weapon

Failure to eject 7 or more rounds - 2 weapons

Failure to fire (hammer spring) - 1 weapon

After zeroing the nine selected weapons under "no wind" conditions, the rear sight on Weapon 17 was halfway to the left, Weapons 9, 35, and 58 were within two clicks of full left windage, and Weapons 11, 51, and 52 were within two clicks of full right windage. This reflects improper alinement of the barrel to the upper receiver.

Approximately halfway through the test, the sear pin was lost from Weapon 9. The sear was removed and the weapon was fired without a sear for the remainder of the test. During the last firing exercise, a part was lost or broken that removed all tension from the selector lever of Weapon 11, rendering the weapon inoperable.

To insure that all test weapons were in the same relative state of cleanness, it was decided to perform no weapons cleaning until increased shot group size or an increased number of firing malfunctions indicated that weapons cleaning was necessary. No weapons cleaning was performed during the test. Over a period of five weeks, the weapons were carried to the outdoor range facility 15 days, fired from sandbag support, and exposed to normal dust and grit. During this period, three of the weapons (9, 11, and 35) were used on the Infantry Remoted Target System (IRETS) range, firing approximately 200 rounds each. Some minor weapon malfunctions were experienced during the early part of the test; however, for the last 150 to 175 rounds fired through each of the nine test weapons, not a single malfunction was experienced (except for Weapon 11 discussed above). No precise comparison of shot group size is possible since the initial shot groups were three round groups and the later were ten round groups. However, when Weapons 9, 11, and 35 were used to fire the targets shown in Figure 11, each weapon had fired 700 rounds since being cleaned. The ten round groups average 2.4 cm in size, indicating that no major deterioration of weapons performance had occurred.

At the conclusion of testing, the upper receiver was replaced on Weapon 51. Eight five-round shot groups were fired from a hand held position on a 25 m range, resulting in an average group size of 2.15 cm. Removing four outlying rounds, one from each of four shot groups, resulted in eight shot groups (36 rounds) with an average size of 1.5 cm. During the test this weapon fired a mean shot group size of 5.62 cm. There appears to be little doubt that the upper receiver was the problem; however, there is no testing procedure at direct/general support level that could have identified this as a potential problem. Provided with information that the weapon would not fire an acceptable shot group, it was the judgment of maintenance personnel that the upper receiver of the barrel would have to be replaced. The upper receiver was replaced, using all other original parts from the weapon, and the weapon fired eight good shot groups.

CONCLUSION

ACCURACY

An underlying reason for conducting this test was the concern that many trainees may be trying to qualify with weapons not capable of hitting targets due to worn barrels, hard triggers, etc. An additional concern was the use of a 5.2 cm zeroing circle which does not insure target hits at 300 meters. A 4 cm zeroing criterion would provide for theoretical hits out to 300 m. An investigation of the organizational and direct support maintenance procedures at Army Training Center, Fort Jackson, South Carolina, and Fort Benning, Georgia, indicated that weapons at both locations received comparable maintenance. It is believed that the sixty weapons selected for testing are a representative sample of rifles used by all Army Training Centers. Fifty-eight of the sixty weapons fired a three round shot group that would fit within a 4 cm circle. Weapon 33 fired a 5.2 cm group from the cradle; however, subsequent firings by two different individuals from unsupported positions resulted in a 3.3 cm group and a 2.3 cm group. Weapon 51 fired an 8.8 cm group from the cradle, and 6.7 and 7.9 cm groups from unsupported positions. This weapon was selected for use in all subsequent testing and its influence on overall firing data should be recognized. The following conclusions are derived from the accuracy test:

- The typical M-16 rifle issued to basic trainees is capable of firing a shot group size of 2.1 cm. By applying correct shooting fundamentals, this shot group can be adjusted to fall within a 4 cm circle.

- The standard serviceability checks will identify unserviceable weapons; however, these checks will not identify all bad weapons, and they provide no indication of rifle shooting quality. Firing shot groups with an experienced rifleman is the only means of determining the shooting quality of a weapon.

ZERO PROCEDURES

Another concern was that the zero procedures based on theoretical trajectory curves may not be totally applicable to the typical rifle in the hands of the trainee. These firings confirmed the general accuracy of the zeroing procedure; however, it was found that small sight adjustments (less than 6 clicks) did not move shot group center the expected .7 cm. This is probably due to the adjustments being smaller than the combined total of all variables in the shooting process. As a consequence, during testing several sight change decisions were made based on previous shot groups as opposed to information provided by the last shot group alone. The conclusions from this test are:

- Adjusting sights to hit 2.4 cm below point of aim at 25 m provides for an adequate 250 m zero. (Confirmation of the zero at 250 m would improve the zero for some weapons.)

- For small sight changes, previous shot groups fired should be given as much consideration as the last shot group in determining sight changes to be made.

LONG RANGE SIGHT

Throughout the research effort on marksmanship, the complexity of information presented to the trainee has been of concern. It appears that some confusion could be eliminated if the initial firings were conducted so that bullet impact was the same as point of aim. Theoretical information indicates that adjusting point of aim to point of impact at 25 m, using the long range sight, will result in an acceptable battle sight zero. This expectation was supported by the data from Test 3. The ability to hit where the rifle is aimed has an important training implication. The role of the 25 m range can be expanded beyond that of merely providing for the zeroing of weapons. Additional exercises can be developed based on scaled silhouette targets which are designed to give the same visual perception when viewed at 25 m as an actual target viewed at range. The target at Appendix N was developed for use at 25 m, using the long range sight, to assist in the transition from 25 m firing to field fire targets. The target at Appendix O was developed as a timed fire exercise to provide practice in the rapid application of shooting fundamentals prior to practice record fire. The results from limited field testing of these targets indicate that their use increases performance on record fire. The zero target at Appendix P was designed to eliminate the Canadian bull from the basic marksmanship program. Using this technique, the requirement to transition from the Canadian bull to silhouette targets would be eliminated. The initial field testing of this concept did not show an improvement in record fire scores; however, additional testing is required to adequately evaluate the concept. The following conclusions were reached:

- When bullet impact is adjusted to coincide with point of aim at 25 m, using the long range sight, an adequate 250 m battle sight zero, using the regular sight, results.

- Using the scaled silhouette target at 25 m presents a similar visual perception as that of the natural target viewed at range.

- Shot group size does not deteriorate when a scaled silhouette target is used in lieu of a Canadian bull at 25 m.

TRAJECTORY

These tests indicate that the typical rifle fires close to the theoretical trajectory curve. These firings indicate that:

- The theoretical trajectory information is accurate for the typical rifle.

- An aiming point somewhat above center of mass is indicated for 300 m targets.

RIMFIRE ADAPTER

Limited firings were conducted with the rimfire adapters. However, definite trends emerged. Several targets are presented in Figures 9, 10, and 11 to assist the reader in evaluating the potential of rimfire adapters. The following conclusions are derived from these firings:

- The weapon malfunction rate increases to an unacceptable level when rimfire adapters are used. (It is understood that these problems are being corrected.)

- Using the rimfire adapter will not result in an adequate weapon zero.

- o Increased shot group size will result from using the rimfire adapter.

- o The rimfire does not produce the noise and recoil of service ammunition - two factors trainees must adjust to during marksmanship fundamentals training.

- o A considerable variability exists among various combinations of rimfire adapters and rifles. It appears that an exhaustive trial and error procedure could be utilized to match rimfire adapters to particular rifles that may provide adequate zeros and relatively small shot groups, while a random pairing of adapters and rifles results in unacceptable performances of rimfire adapters.

EFFECTS OF BARREL STRESS

The relatively light barrel on the M-16 is subject to distortion from various forms of external stress. The data of Test 6 clearly indicate that any pressure applied to the forward portion of the rifle will have some influence on changing the strike of the bullet. For example, the difference in bullet strike between using a hasty sling and using a bipod may be as much as four feet at 300 m. The following conclusions are reached:

- o Any stress placed on the forward portion of the M-16 will influence bullet strike.

- o The M-16 must be zeroed with the exact pressures to be used in firings, i.e., hasty sling, bipod, etc.

- o Stress placed on the forward portion of the M-16, in any form, should be avoided.

FIRER ERROR

The relative contribution of various firer errors to the misplacement of bullets on the target is very important in the teaching of marksmanship fundamentals. This test included numerous firings designed to determine the relative worth of steady hold factors and various marksmanship fundamentals; however, the data produced were not amenable to statistical analysis and are not included in this report. The implications of these data are addressed in a subsequent report. The following conclusions are derived from the data in this report:

- Sight alinement error is currently given too much emphasis. It is probably not a major contributor to trainees missing targets.

- Rifle cant, while having some influence on the impact of rounds, is not a major contributor to target misses.

- Minor changes in eye relief positions have minimal effect on bullet strike.

COMMERCIAL AMMUNITION

No attempt is made in this report to explain the improvement in weapons performance by switching to commercial ammunition. However, it may be concluded that:

- Some changes could be made to service ammunition that would improve weapons performance.

APPENDIX A

AMMUNITION INSPECTION REPORT

Lot #LC-2-421

LC 2443 Rev. 12/28/68 (3/9/73)

DATE PRESENTED 4/30/73
QUANTITY PACKED 2, 1,440
FSN 1305-926-3930-(A071)

FUNCTIONAL LOT NOS.

AMCMS CODE
4110.16.0229, FY73

SPEC NO MIL-C-9963E REV
ECO DATE 5/12/70
DWG NO D-10523632
REV K DATE 8/30/71

REMINGTON ARMS COMPANY, INC
Lake City Army Ammunition Plant

INSPECTION REPORT - 5.56MM

ITEM Ctg. Ball, M193

LOT NO. LC-2-431

ACCEPTED ☒ 1st TEST ☒
REJECTED ☐ RETEST ☐
WAIVER ☐

ACCEPTANCE DATE 11 Sept. 1973

CONTRACTOR Remington Arms Co., Inc
CONTRACT NO. DAAA09-71-C-0316
PRIMER NO. 41 MIX FA 956
PRIMER LOT NOS. 15-243; 249

PROPELLANT TYPE WC 844-Radcer
A.L. NO. 47376

CHG (GRS) 25.4
CASE - STEEL ☐ BRASS XX
HEADSTAMP (YR) LC73
BULLET JACKET Gilding metal

FIRING TESTS	RDS. FIRED	RECORD	SPEC. LIMITS
VELOCITY @15Ft (F.S)			
Corrected Avg (Amb)	20	3250	3250±40
Standard Deviation	XXXX	25.0	40 Max.
125°	20	+62	-250
160° Reduced to 70°			From
-65°	20	-77	Avg.
CHAMBER PRESSURE (PSI) *			
Corrected Avg. (Amb)	20	47400	52000 Max.
Avg. + 3σ (Amb)	XXXX	51300	58000
125°	20	+800	+5000
160° Reduced to 70°			From
-65°	20	-1400	Avg.
PORT PRESSURE *			
Corrected Avg. (Amb)	20	15260	15000 ±2000
125°	20	-280	±2000
160° Reduced to 70°			From
-65°	20	-600	Avg.
ACCURACY (Inch) @200 Yds.			
Mean Radi:	90	1.6	2.0 Max.
ACTION TIME (MS)	50	1.13	4.0 Max.
TRACE @500 Yds.			
No. Tracing			Min.
No. Bullet Bursts	XXXX		
No. Erratic Flights	XXXXX		
No. Muzzle Flashes	XXXX		

FIRING TESTS

FUNCTION

RDS. FIRED	Amb.	125° ± 2°	160° ± 2° REDUCED to 70° ± 2°	-65° ± 2°	RECORD	Sp. Lt.
RIFLE	240	240		240	**	
RIFLE	240	240		240	OK	

CASUALTIES ** 4 Small Primer Leakers-44 allowed.

NON FIRING TESTS	No. Tested	Record	Sp. Lt.
CARTRIDGE			
Waterproof (Vac)	50	0	3
BULLET			
Extraction (Lbs) Record: Mean 68 Max. 98	25	51 Min.	Min. 35
Base Closure Seal			
CASE			
Residual Stress (Mercurous Nitrate) Record:	50	OK	0

TOTAL Authorized Rds. Expended in Tests 1810

Lot inspected in accordance with contract requirements (Except as otherwise authorized and noted hereon).

REMARKS: Accepted per TDPL A10535861 dated 5-6-71.
100 Rounds Stripping Test - OK
Diamond Pyramid Hardness Test - OK
*Fired Simultaneously.

AIR FLOW

GUN	BEFORE	AFTER
427	1.65	1.65
457	1.65	1.65

Fouling - Medium

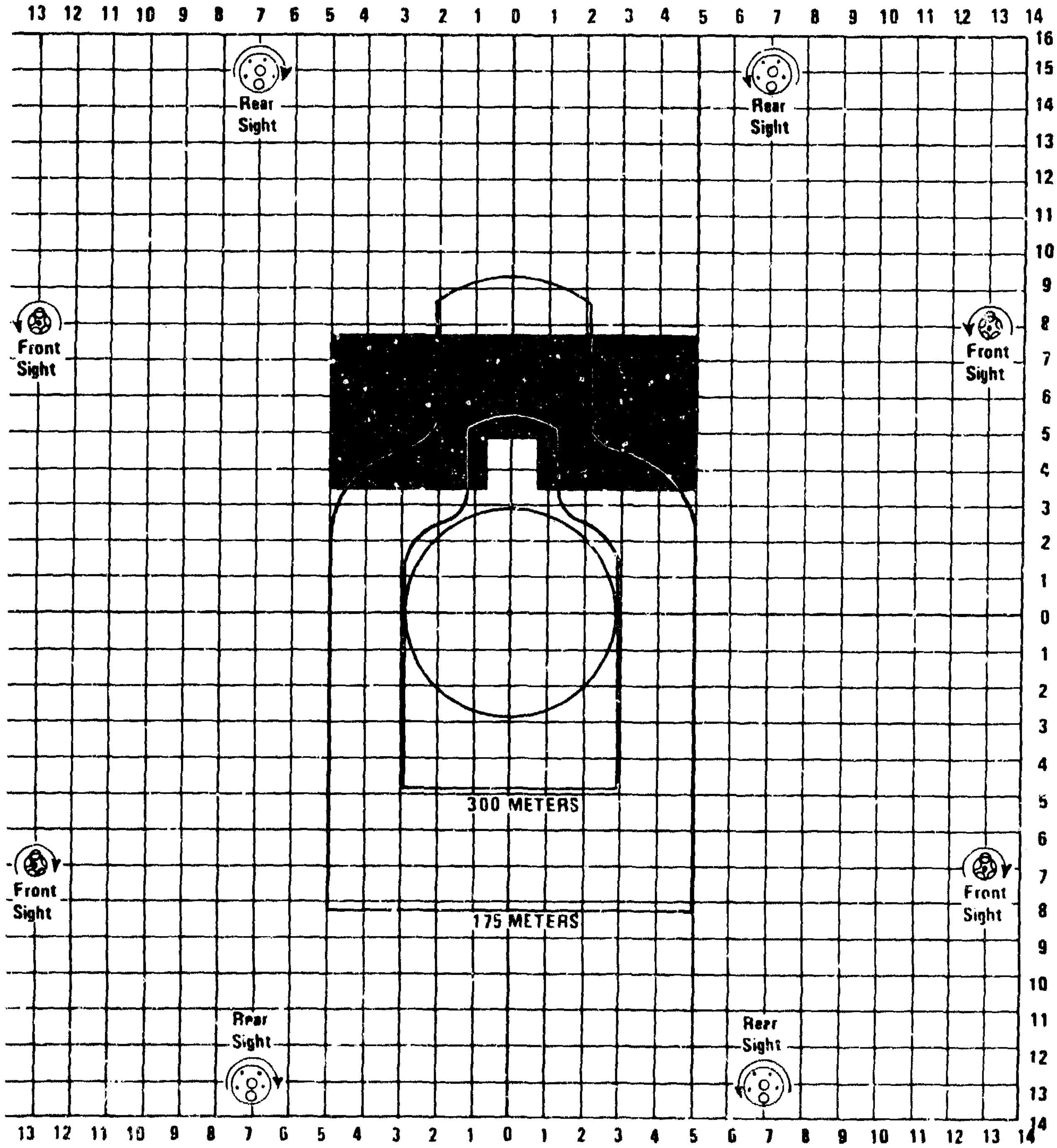
CX-10-round clips (Assoc. Spring)
This lot packed with M2A1 Metal Boxes manufactured by Kaiser (metal boxes directed by Government correspondence SMULC-CA dated 9/16/71).

APPENDIX B

ARI ZEROING TARGET

(Left side cut to fit 8" width)

ARI 25 METER ZEROING TARGET



TO ZERO MOVE SHOT GROUP CENTER TO BLACK DOT. CLICK EACH SIGHT THE NUMBER OF TIMES MARKED ON LINE.

APPENDIX C
TEST 1 DATA

Weapon Test No.	Serial No.	M[1]	FS[2]	Local[3] Source	STANDARD ARMY TESTS Barrel Straight-ness	Head Space	Bore Erosion	Mean[4] Muzzle Velocity	Standard[4] Deviation of muzzle velocity	Trigger[5] Pull	SHOT GROUP SIZE[6] Cradle	Firer 1	Firer 2
1	3225699	GM	C	AIT	P	P	P	3169	30	7.5	2.0	3.0	3.1
2	5090793	C	C	AIT	P	P	P	3152	17	7.5	2.3	2.3	3.2
3	3252422	GM	C	AIT	P	P	P	3163	30	8.0	3.3	2.1	3.4
4	3223069	GM	C	AIT	P	P	P	3107	18	9.0	1.5	2.8	4.6
5	132749	C	C	AIT	P	P	P	3086	17	8.0	2.0	1.5	3.0
6	3185614	GM	C	AIT	P	P	P	3106	57	7.5	2.3	2.5	4.0
7	3248877	GM	C	AIT	P	P	P	*	*	4.5	1.8	*	*
8	3306483	GM	C	AIT	P	P	P	3132	29	8.0	1.0	3.8	2.4
9	117485	C	C	AIT	P	P	P	3124	17	7.5	1.4	1.5	3.3
10	3251171	GM	C	AIT	P	P	P	1359	10	8.5	1.5	2.5	5.3
11	3249992	GM	C	AIT	P	P	P	3146	8	8.5	1.1	0.8	3.8
12	3382517	GM	C	AIT	P	P	P	3161	2	7.5	3.0	2.2	4.4
13	3252546	GM	C	AIT	P	P	P	3150	31	8.5	2.3	1.6	4.7
14	3252457	GM	C	AIT	P	P	P	3123	10	7.5	3.1	2.7	4.0
15	3249435	GM	C	AIT	P	P	P	3119	7	10.5	1.0	2.2	2.7
16	3241783	GM	C	AIT	P	P	P	3050	34	7.5	1.8	3.3	3.5
17	3247789	GM	C	AIT	P	P	P	3184	13	10.0	0.4	1.8	4.5
18	3250418	GM	C	AIT	P	P	P	3107	25	7.0	1.5	3.3	1.8
19	3225152	GM	C	AIT	P	P	P	3104	45	8.5	1.4	1.5	8.5
20	3252979	GM	C	AIT	P	P	P	3188	21	7.0	2.2	3.3	4.9
21	3244534	GM	C	AIT	P	P	P	3163	19	6.0	0.7	1.2	5.0
22	3251547	GM	C	AIT	P	P	P	3115	7	7.5	1.8	2.1	3.2
23	3253229	GM	C	AIT	P	P	P	3137	10	8.5	2.3	4.5	2.0
24	3262113	GM	C	AIT	P	P	P	3105	12	8.5	1.5	2.6	3.3
25	3244373	GM	C	AIT	P	P	P	3124	4	7.0	1.5	3.7	3.4
26	3248830	GM	C	AIT	P	P	P	3141	13	10.5	1.6	1.7	1.4
27	3239761	GM	C	AIT	P	P	P	3131	19	7.0	2.0	3.9	2.2
28	3248253	GM	C	AIT	P	P	P	3151	13	7.5	1.7	2.0	3.5
29	3015801	GM	C	AIT	P	P	P	3109	10	9.0	1.0	1.5	1.9
30	3261976	GM	C	AIT	P	P	P	3165	19	8.5	1.3	2.1	5.6
31	114189	C	O	KH	P	P	P	3210	12	7.5	3.3	1.7	2.7
32	119660	C	C	KH	P	P	P	3200	4	7.0	1.4	1.4	5.5
33	547652	C	C	KH	P	P	P	3086	15	10.0	5.2	-	2.3
34	4425125	C	C	KH	P	P	P	3173	7	8.0	2.5	-	6.4

APPENDIX C
TEST 1 DATA (Continued)

Weapon Test No.	Serial No.	M[1]	FS[2]	Local[3] Source	STANDARD ARMY TESTS Barrel Straightness	Head Space	Bore Erosion	Mean[4] Muzzle Velocity	Standard[4] Deviation of muzzle velocity	Trigger[5] Pull	SHOT GROUP SIZE[6] Cradle	Firer 1	Firer 2
35	120840	C	C	KH	P	P	P	3100	24	8.5	2.1	3.0	2.7
36	108045	C	C	KH	P	P	P	3145	15	8.0	2.2	1.6	3.0
37	586527	C	C	KH	P	P	P	3118	2	8.5	1.2	3.3	4.3
38	3182038	GM	C	KH	P	P	P	3145	13	8.0	1.8	1.8	4.7
39	3165508	GM	O	KH	P	P	P	3161	14	7.0	2.6	2.0	3.0
40	4588122	C	C	KH	P	P	P	3199	19	7.5	1.3	2.8	2.9
41	513840	C	C	KH	P	P	P	3187	13	7.5	2.5	2.8	2.8
42	3181603	GM	O	KH	P	P	P	3140	7	7.5	1.3	3.0	2.1
43	509397	C	O	KH	P	P	P	3129	17	7.5	2.6	2.4	2.5
44	3183743	GM	C	KH	P	P	P	3184	2	6.5	2.4	3.1	3.4
45	515276	C	C	KH	P	P	P	3173	15	7.5	2.0	4.3	5.5
46	105538	C	O	KH	P	P	P	3202	21	9.0	3.2	1.3	2.4
47	811026	C	O	KH	P	P	P	3173	10	7.5	2.5	1.5	3.2
48	505495	C	C	KH	P	P	P	3163	21	8.5	2.3	1.2	3.5
49	3182933	GM	C	KH	P	P	P	3154	17	8.5	1.3	3.2	4.7
50	3165940	GM	C	KH	P	P	P	3173	9	7.5	1.4	1.9	2.5
51	3183833	GM	O	KH	P	P	P	3167	18	8.5	8.8	6.7	7.9
52	512453	C	O	KH	P	P	P	3135	4	5.5	1.3	2.9	1.5
53	3182697	GM	C	KH	P	P	P	3181	37	7.0	1.3	2.5	4.2
54	112147	C	C	KH	P	P	P	3194	11	8.5	2.0	1.7	2.4
55	3165502	GM	C	KH	P	P	P	3199	24	7.5	2.0	1.7	3.3
56	804694	C	O	KH	P	P	P	3172	27	7.0	3.8	1.7	5.5
57	3185066	GM	O	KH	P	P	P	3129	18	7.5	2.8	1.7	1.9
58	509297	C	C	KH	P	P	P	3151	9	8.5	1.5	2.9	4.5
59	505306	C	C	KH	P	P	P	3179	23	8.0	1.4	3.7	2.4
60	119395	C	O	KH	P	P	P	3193	25	6.5	3.7	6.2	3.7

[1] Manufacturer
GM= General Motors
C= Colt

[2] Flash Suppressor

[3] Army Individual Training
KH= Kelly Hill

[4] Feet/Second

[5] Pounds

[6] Centimeters

*Weak hammer spring, eliminated from test

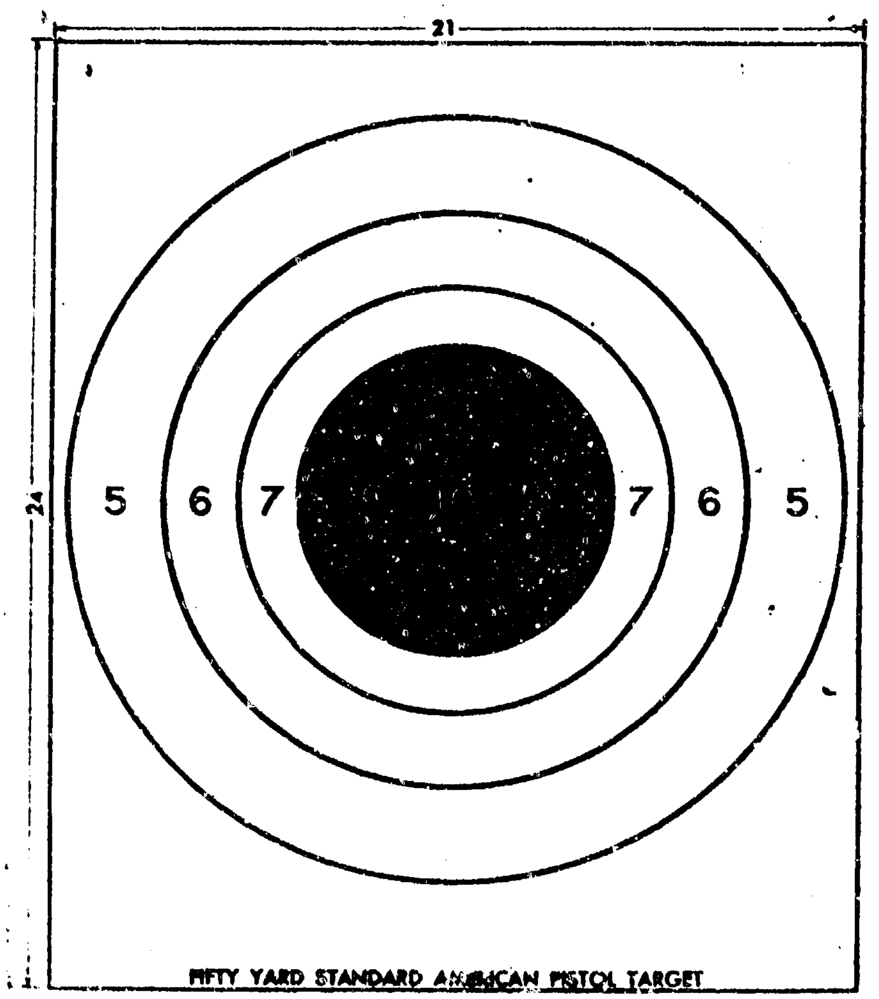
APPENDIX D

FIFTY YARD STANDARD AMERICAN PISTOL TARGET

(Used in Tests 2 and 4)

(21 Inches)

(24 Inches)



APPENDIX E

Test 2 Data

	Weapon Number								
	9	11	17	35	41	51	52	57	58
Number of shot group to zero	6	4	4	5	4	4	4	1	4
Mean shot group size	2.61	1.58	2.15	2.00	5.80	3.98	2.13	1.90	1.90
Final shot group size (zero)	2.4	1.6	2.0	2.6	6.5	3.3	3.0	2.6	2.2
Displacement of zero shot group:									
Vertical	0	-.2	-.7	-.6	-.8	+1.1	-.7	-.7	-1.0
Horizontal	+ .9	-.8	0	+.6	-.2	+ .1	+.9	+.4	- .5
250 m shot group size	13.1	14.3	38.6	15.3	47.7	31.1	16.5	17.6	9.7
Displacement of 250 m shot group:									
Vertical	+4.9	-6.7	-17.6	+6.8	-4.9	+10.6	+2.4	-24.6	-3.0
Horizontal	+1.8	-14.0	+0.8	+10.8	-12.8	+18.7	+13.1	+ 8.18	-2.6
25 m LR sight shot group size	1.9	1.2	2.1	2.0	5.7	5.5	2.7	1.1	4.7
25 m LR shot group displacement:									
Vertical	0	-1.3	-1.6	+1.4	+.5	+2.0	+.7	-1.2	0
Horizontal	-.5	-1.0	+1.8	- .9	+.9	+ .3	+.6	+1.7	+.6

Note: All tabled values are in centimeters

APPENDIX F

Movement of Center of Shot Group as a Function of Number of Clicks Elevation and Windage

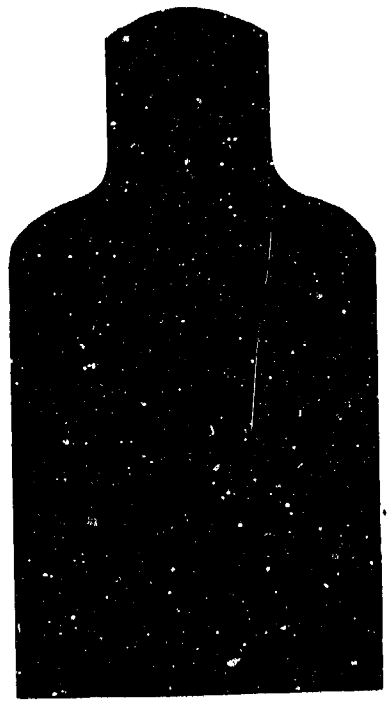
Number of Clicks	Elevation: Mean mm Movement per click	Elevation: Number of Cases	Windage: Mean mm Movement per click	Windage: Number of Cases
1	11.5	12	13.9	12
2	10.3	8	9.8	8
3	6.8	2	9.8	2
4	11.1	2	-	-
5	11.2	1	11.0	1
6	11.2	1	-	-
7	8.4	1	-	-
8	8.5	1	5.0	1
9	6.8	1	-	-
10	7.8	1	-	-
14	7.5	1	5.4	-
15	8.2	1	-	-
19	-	-	5.7	1

APPENDIX G

SCALED SILHOUETTE TARGET

(This target, scaled to represent an "E" type silhouette at 250 m when viewed from 25 m, is shown actual size.)

Note: This plain silhouette target was used in this test; however, a silhouette was superimposed on the new ARI Zeroing Target (see Appendix P) for field testing.



APPENDIX H
Test 3 Data

Range and Type of Sight	Observation	Weapon Number: 9	11	35	41	51	58
25 m LR	Cradle Shot Group Size	2.0	1.3	1.4	2.0	3.6	3.7
	Displacement:						
	Vertical	+.3	-1.0	-.2	-.1	+.5	+1.0
	Horizontal	+1.0	+.8	-.4	-1.0	-1.1	+.7
25 m LR	Firer 1 Shot Group Size	1.3	2.5	2.9	2.8	4.7	3.9
	Displacement:						
	Vertical	-1.0	-1.7	+1.1	+.4	+1.2	-1.3
	Horizontal	+.2	+.6	+1.1	-.8	+1.3	+.8
25 m LR	Firer 2 Shot Group Size	2.8	1.5	2.8	2.7	2.5	1.2
	Displacement:						
	Vertical	0	-1.5	+1.5	-.2	+1.0	+.1
	Horizontal	0	-.6	-.2	-1.0	-.7	-1.0
250 m RS	Cradle Shot Group Size	28.0	19.9	13.5	15.9	25.2	33.7
	Displacement:						
	Vertical	0	+8.9	+.9	-18.4	+4.3	+1.0
	Horizontal	-2.5	-.9	-2.9	0	+14.2	-18.2
250 m RS	Firer 1 Shot Group Size	25.5	31.8	7.7	33.8	25.8	32.7
	Displacement:						
	Vertical	-3.8	+5.1	-.7	-.9	-20.9	+6.8
	Horizontal	+9.8	+3.2	+12.7	+.7	+28.8	-17.2
250 m RS	Firer 2 Shot Group Size	37.9	22.7	55.4	34.9	50.3	41.3
	Displacement:						
	Vertical	-8.9	-9.6	-8.0	+14.0	-3.8	+15.5
	Horizontal	+17.3	+7.0	-9.1	-10.8	+19.4	-19.2

Note: All tabled values are in centimeters. LR = Long Range Sight RS = Regular Sight

APPENDIX H
Test 3 Data (Continued)

Range and Type of Sight	Observation	Weapon Number 9	11	35	41	51	58
	Cradle Shot						
	Group Size	3.1	2.2	1.8	2.2	5.8	3.7
25 m	Displacement						
RS	Vertical	+2.1	+2.9	+.4	+1.0	-1.2	+1.6
	Horizontal	+1.8	-.2	-.3	+.2	+.2	+1.1
	Firer 1						
	Shot Group Size	2.7	1.0	2.6	3.0	3.8	3.0
25 m	Displacement:						
RS	Vertical	+2.3	+1.4	+1.8	+1.5	-.3	-.4
	Horizontal	+ .3	-.2	-.3	+1.0	+1.2	+1.5
	Firer 2						
	Shot Group Size	2.9	4.0	2.7	3.3	11.3	3.1
25 m	Displacement:						
RS	Vertical	+.8	0	+1.3	+2.9	-.3	+2.5
	Horizontal	0	-.7	-2.1	-.3	+.4	-1.8

Note: All tabled values are in centimeters.

APPENDIX I
Test 4 Data

Range	Observation	Weapon Number								
		9	11	17	35	41	51	52	57	58
	Mean Shot Group Size	2.10	2.18	2.00	2.70	2.0	3.10	2.98	4.73	4.90
25 m	Mean Displacement of zero shot group:									
	Vertical	-.4	-.5	-1.2	-.6	-.1	+1.3	-.4	-.9	+1.0
	Horizontal	-.6	-.7	+.6	-.6	-1.0	-.3	+.4	-.6	+.5
150 m	Shot Group Size	15.3	11.3	18.5	14.9	8.8	24.3	18.3	27.2	29.8
	Displacement									
	Vertical	+4.8	+9.9	+.5	+5.6	+4.0	-2.0	+3.2	+11.0	+6.9
	Horizontal	+5.8	-10.6	_.3	+10.7	+3.7	+5.0	-1.7	-1.2	+6.4
250 m	Shot Group Size	46.0	20.0	26.7	20.9	20.8	53.5	18.6	40.2	33.8
	Displacement									
	Vertical	+1.3	-5.3	-11.3	+2.0	+5.5	-6.6	-1.0	+6.6	0
	Horizontal	-3.5	-1.7	+2.8	-3.0	+2.2	+17.6	-4.3	+4.0	-18.4
300 m	Shot Group Size	32.1	23.7	20.1	17.6	28.0	40.5	16.2	53.3	44.5
	Displacement:									
	Vertical	-15.5	-27.2	-12.4	-8.9	-7.5	-28.5	-7.6	-16.8	-28.7
	Horizontal	-.7	-3.0	-7.1	+22.3	-13.4	+15.7	-7.0	-15.4	-15.0
25 m	Shot Group Size	2.1	1.9	2.7	1.7	2.3	6.4	2.5	3.5	3.7
	Displacement									
	Vertical	+.3	-.5	-.4	+1.3	+1.0	-2.2	-.4	+.7	+1.5
	Horizontal	-.2	+1.0	+1.0	+.8	+1.2	-.8	-1.7	-.1	+1.7

Note: All tabled values are in centimeters

APPENDIX J
Test 5 Data

Weapon (Hand held)	Shot Group Size/Vertical Displacement/horizontal displacement	
	5.56 mm	.22 cal
9	3.2/-1.1/-.1	6.5/+3.8/-1.3
11	1.8/+.9/+.6	4.5/+4.3/+1.9
17	3.5/+.4/-.2	3.2/-2.1/+.5
35	3.9/+.3/+.4	7.9/-.3/+.5
41	3.4/+1.5/+.2	6.0/+3.3/+1.8
51	4.0/+2.0/-2.7	7.3/-1.7/+4.4
52	1.8/-.1/+.1	3.0/+1.6/+.8
57	3.7/-1.6/+.5	3.8/-1.4/-.7
58	4.3/-1.1/+.1	3.8/-.8/-.6
Mod. M16	2.2/+3.2/0	6.7/+4.2/+2.1

Note: All tabled values are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -.

APPENDIX J
Test 5 Data (Continued)

Shot Group Size/Vertical Displacement/ Horizontal Displacement (Hand Held Weapons)

Rimfire Adapter Number	Mod. M16	9	11	41	51	58
8	6.2/+1.9/+.7	5.6/+1.9/+.7	5.6/3.8/-1.1	5.1/+5.5/0	6.1/+4.3/+3.9	3.7/+.7/-.9
25	5.8/+1.2/-1.5				6.1/+4.3/+3.9	
46	6.6/+1.5/+.2					
59	4.3/+.5/-.2			5.1/+3.3/+3.6		
74	3.9/+2.2/-.3					
ZEROS	3.3/+.4/-.2 3.2/+.2/-.2	2.7/-1.2/-.2	2.9/+.3/0	3.4/+1.5/+.2	7.4/+1.7/-.7	3.7/+.5/+.3

Shot Group Size/Vertical Displacement/ Horizontal Displacement Cradle Fired Weapons

Rimfire Adapter Number	Mod. M16	9	11	35	41	51	58
8	5.1/+.6/-1.0	5.6/+3.8/-1.1					
25						9.2/-3.2/+2.4	2.8/-1.5/-2.7
46			3.3/+3.6/+1.9	3.5/-2.6/-.4			
59					6.3/+1.8/+7.3		
74							
ZEROS	3.1/+.1/-.4	2.7/-1.2/-.2	2.1/+1.0/+.3	2.6/+1.8/-.4	4.2/-2.1/+1.3	6.3/+1.1/+.1	4.7/-.6/-1.7

Note: All tabled values are in centimeters.

APPENDIX K
Test 6 Data

Weapon Number	Shot Group Size and Displacement	Zero	Hasty Sling	Bipod-Bench w/ pressure down	Bipod-pull to rear	Loop Sling	Weapon on bayonet stud pressure down	Rear Pressure Front hand guard
	Size	2.8	1.9	1.8	2.1	3.4	3.4	2.6
9	Vertical Disp	+.42	-2.96	+5.99	.00	-1.28	+5.12	+.70
	Horizontal Disp	+.47	+.11	+.42	-.68	+.6	-.64	-.16
	Size	1.9	2.6	3.1	3.1	4.3	3.2	2.4
11	Vertical	+.86	-1.9	+2.58	-3.95	-.80	+9.01	+1.66
	Horizontal	+.06	+ .38	-.96	-.81	-.41	+.57	+.15
	Size	2.3	3.2	2.1	2.6	4.0	3.3	2.6
35	Vertical	-.19	-4.78	+5.80	-.78	-3.05	+5.88	+.73
	Horizontal	-.16	-.94	-2.19	-2.47	-.48	-.46	+.21
	Size	3.3	4.4	4.9	2.9	3.6	4.9	3.1
41	Vertical	+1.4	-5.42	+10.38	-1.81	-1.94	+7.03	-.43
	Horizontal	-.78	+.68	+2.56	-3.58	-.18	+1.18	+.28
	Size	3.9	11.0	7.9	7.6	12.5	7.2	7.9
51	Vertical	+.15	-8.38	+.79	-6.47	-6.50	+2.96	-.83
	Horizontal	+.76	+4.54	+4.25	+3.04	+.98	+2.53	-1.04
	Size	5.4	6.5	5.6	2.8	5.0	4.1	5.4
58	Vertical	+.68	-3.84	+5.66	-.94	-2.58	+5.00	-.48
	Horizontal	+1.14	+.86	+1.0	+1.73	-1.36	+.38	+.34

Note: All tabled values are in centimeters. Displacement below zero coordinates denoted by -. Displacement left of zero coordinates denoted by -.

APPENDIX L
Test 7 Data

Weapon Number	Shot Group Size and Displacement	Eye Relief				
		Eye directly behind peep sight	Tip of nose on charging handle	Nose over charging handle	Nose 2" behind charging handle	Face 1/2 back on stock
	Size	1.8	2.8	2.2	1.5	1.5
9	Vertical	+.88	+.42	-.31	-1.60	+.05
	Horizontal	-.42	+.47	-.66	-.38	+1.54
	Size	2.4	1.9	2.2	1.8	2.1
11	Vertical	+1.54	+.86	+1.96	+.73	+2.36
	Horizontal	+.42	+.06	+.58	+1.25	+1.94
	Size	2.8	2.3	2.8	1.7	3.7
35	Vertical	-.05	-.19	+.24	+.22	+1.11
	Horizontal	-.52	-.16	-.16	-.46	+.42
	Size	1.9	3.3	2.5	3.2	3.2
41	Vertical	+.73	+1.4	+1.61	+.28	+.87
	Horizontal	-.77	-.78	-.04	+.16	+2.48
	Size	7.5	3.9	12.5	4.0	11.5
51	Vertical	+.30	+.15	-1.72	-1.20	+1.05
	Horizontal	+.83	+.76	+3.16	+2.59	+1.72
	Size	1.8	5.4	4.7	3.0	3.2
58	Vertical	+1.02	+.68	+.50	-.72	-.44
	Horizontal	+.60	+1.14	+1.38	+.70	+.80

Note: All tabled values are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -.

APPENDIX K
Test 6 Data

Weapon Number	Shot Group Size and Displacement	Zero	Hasty Sling	Bipod-Bench w/ pressure down	Bipod-pull to rear	Loop Sling	Weapon on bayonet stud pressure down	Rear Pressure Front hand guard
	Size	2.8	1.9	1.8	2.1	3.4	3.4	2.6
9	Vertical Disp	+.42	-2.96	+5.99	.00	-1.28	+5.12	+.70
	Horizontal Disp	+.47	+.11	+.42	-.68	+.6	-.64	-.16
	Size	1.9	2.6	3.1	3.1	4.3	3.2	2.4
11	Vertical	+.86	-1.9	+2.58	-3.95	-.80	+9.01	+1.66
	Horizontal	+.06	+ .38	-.96	-.81	-.41	+.57	+.15
	Size	2.3	3.2	2.1	2.6	4.0	3.3	2.6
35	Vertical	-.19	-4.78	+5.80	-.78	-3.05	+5.88	+.73
	Horizontal	-.16	-.94	-2.19	-2.47	-.48	-.46	+.21
	Size	3.3	4.4	4.9	2.9	3.6	4.9	3.1
41	Vertical	+1.4	-5.42	+10.38	-1.81	-1.94	+7.03	-.43
	Horizontal	-.78	+.68	+2.56	-3.58	-.18	+1.18	+.28
	Size	3.9	11.0	7.9	7.6	12.5	7.2	7.9
51	Vertical	+.15	-8.38	+.79	-6.47	-6.50	+2.96	-.83
	Horizontal	+.76	+4.54	+4.25	+3.04	+.98	+2.53	-1.04
	Size	5.4	6.5	5.6	2.8	5.0	4.1	5.4
58	Vertical	+.68	-3.84	+5.66	-.94	-2.58	+5.00	-.48
	Horizontal	+1.14	+.86	+1.0	+1.73	-1.36	+.38	+.34

Note: All tabled values are in centimeters. Displacement below zero coordinates denoted by -. Displacement left of zero coordinates denoted by -.

APPENDIX L
Test 7 Data (Continued)

Weapon Number	Shot Group Size and Displacement	Cant Left	Zero	Cant Right	Breath Jerk flinch
	Size	3.7	2.8	2.6	4.8
9	Vertical	-.64	+.42	+.77	-.77
	Horizontal	+1.50	+.47	-1.88	-.43
	Size	3.3	1.9	2.8	7.4
11	Vertical	+.50	+.86	+.36	-2.65
	Horizontal	+.89	+.06	+.64	+.48
	Size	3.6	2.3	3.0	8.9
35	Vertical	+.15	-.19	-.85	-.17
	Horizontal	+.50	-.16	-.96	-1.08
	Size	2.7	3.3	3.2	7.7
41	Vertical	-1.59	+1.4	-.05	+2.44
	Horizontal	+1.44	-.78	-1.39	+.20
	Size	9.1	3.9	10.3	20.5
51	Vertical	-2.10	+.15	-2.51	+.60
	Horizontal	+1.72	+.76	+2.44	-.95
	Size	2.9	5.4	2.4	4.0
58	Vertical	-.02	+.68	-1.73	+1.08
	Horizontal	+1.32	+1.14	-.16	+.29

Note: All tabled values are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -.

APPENDIX M

Test 8 Data

TRAINEE FIRING - SHOT GROUP SIZE

Trainee	Weapon Number																			
	9		11		17		35		41		51		52		57		58		Mod. M16	
No.	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL	ARE	SIL	ARI	SIL	ARI	SIL
1	2.7	2.2	3.5	2.5	10.5	2.3	1.2	1.8	1.8	4.5	3.4	2.2	5.8	2.7			2.6	2.0	3.1	
2	3.6	3.3	2.6	1.3	5.7	6.2	4.6	2.2	2.7	2.4	6.4	4.5			1.7	3.5	4.2	3.8	2.3	4.5
3	2.3	3.7			2.5	3.3	2.3	4.6	2.8	2.3	2.8	4.3	3.1	4.5	2.3	2.2	2.7	2.2	2.4	3.8
4	3.3	7.3			7.0		3.3	4.5			4.8	3.8	2.3	1.8	2.1	4.3	1.7	3.8	3.2	4.1
5					3.9	4.6			4.6	1.8	4.4	3.2	1.5	2.0	8.1	2.8	3.4	2.8	2.4	3.2
6	3.8	10.6					2.0	7.1	5.2	3.8	7.4	5.7	6.4	5.2	5.1	3.9	3.9	4.7		
7	2.7	4.9			2.8	5.3	2.3	4.6	2.5	3.4			2.7	2.3	1.5	3.3				
8	4.6	6.4			6.2	1.8	2.9	3.1	3.5	5.2	4.5	4.2	5.8	2.7	2.4	3.2			0.8	2.8
9	1.7	1.0			2.4	3.1					3.0		2.7	1.4	3.5	2.4	2.0	2.5		2.6
10	4.6	4.2					5.6	4.0	1.3	2.7	3.8	9.0	2.1	1.5	3.0	1.8	1.5	3.2	2.8	3.6

Note: ARI = ARI target (Appendix B)
SIL = Silhouette target (Appendix F)
All tabled values are in centimeters

APPENDIX M
Test 8 Data (Continued)

TRAINEE FIRING - WINDAGE & ELEVATION

Trainee Number	Weapon Number 9 ARI	9 SIL	11 ARI	11 SIL	17 ARI	17 SIL	35 ARI	35 SIL	41 ARI	41 SIL
1	.2/2.2	1.1/.2	0/.9	-.3/1.3	-3.4/-2.6	-3.0/-2.5	-.2/1.3	.2/1.9	1.8/-1.5	1.4/1.0
2	1.5/2.3	-.4/2.7	2.6/-2.0	0/-1.9	-1.1/-1.4	-3.0/-3.2	.5/-1.3	3.9/1.5	1.1/-.8	2.2/.6
3	-.5/1.8	-.7/1.5			.2/-.8	-.2/-3.0	-.2/1.1	1.0/-2.1	.3/-2.4	.1/-3.8
4	-1.2/2.2	-1.2/-3.0		-3.7/-6.2	-3.2/-3.4	-1.7/-1.9	-1.8/1.5			
5					-2.9/-2.6	-1.5/-6.0			+.7/-1.6	-.5/+.4
6	-2.4/-3.2	.8/-2.4		.8/-2.4	-.8/-1.2	-.2/-2.4	.6/-.7	-1.1/.2	.9/-2.6	-1.5/-1.7
7	-3.9/2.1	-2.1/-1.1			-3.2/-1.1	-3.2/-2.9	-2.2/1.8	-1.2/0	1.5/3.4	.4/1.1
8	2.1/-1.2	-.9/-.1			0/-4.3	+.5/-.2	-.3/-2.1	1.8/3.1	2.8/-2.3	.8/.4
9	+.2/-1.6	-.2/-3.7			-.8/-3.9	-.7/-3.5				
10	-.5/0	.3/-3.2					2.9/1.9	1.4/1.0	-.2/-.8	.5/-3.4

Note: Number before / sign is windage, and number after the / sign is elevation. All measurements are in centimeters. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -. ARI = ARI target (Appendix B) SIL = silhouette target (Appendix F).

APPENDIX M
Test 8 Data (Continued)

TRAINEE FIRING - WINDAGE & ELEVATION

Trainee	51		52		57		58		Mod M16	
Number	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL	ARI	SIL
1	-1,2.-3.1	-.1/-2.0	0/-.1	0.7/-.5			-1.1/-.1	-3.1/-1.6	.4/-7.2	0/-9.1
2	-3.3/2.1	-2.7/.3			-2.7/-.3	-.8/-3.6	-3.2/-1.1	-1.2/-.4	-.3/-.3	.6/2.3
3	-1.4/0	-.5/.4	-.9/1.3	-1.0/.5	-2.1/-.7	-1.7/2.0	-1.5/-1.5	-1.5/-2.1	.5/7.9	1.8/5.2
4	-2.8/-2.2	-4.5/-4.4	-2.0/-1.6	-1.9/-3.3	-2.7/-5.1	-3.9/-1.4	-.4/-2.1	-2.2/-.7	-1.6/4.5	-2.2/-.9
5	2.0/-4.8	-3/-6.3	-5.1/-1.7	-2.1/-1.5	-4.7/-5.3	-2.9/-5.5	-2.2/-.8	-3.2/-5.6	-.3/3.9	.4/1.6
6	-3.6/-2.8	.2/-1.2	-2.4/-1.4	-1.6/-2.5	-2.4/-.9	.2/-3.4	-2.7/-2.5	6.6/-4.5	-2.0/.6	.6/-.9
7			-2.9/5.5	-2.3/3.6	-3.8/-.7	-4.5/-.7				
8	0/-4.2	.2/.7	1.8/.1	-1.2/3.9	-1.7/.7	-.2/1.7				
9	-3.2/-2.9	-1.1/-5.7	0/-2.4	1.3/-4.2	-1.4/-3.9	-2.3/-3.5	-.7/-1.2	-1.7/-6.3		-1.5/.7
10	-1.0/-4.3	-1.2/-.7	-.1/3.4	.4/-1.1	-.8/-3.9	-.4/-2.5	-1.3/7.1	-.6/-1.6	+.4/-6.3	1.5/-7.4

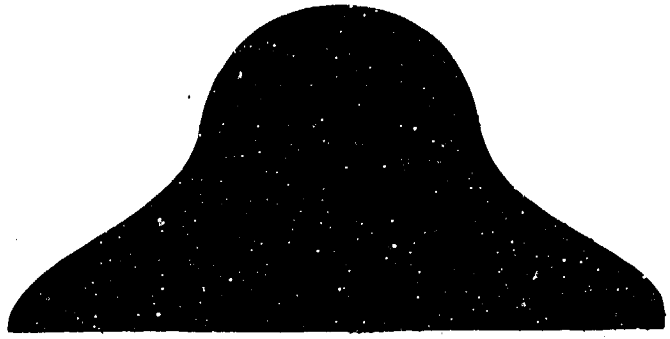
Note: All tabled values are in centimeters. Windage is number before / sign, and elevation is number after / sign. Displacement below intended point of impact is denoted by -. Displacement left of intended point of impact is denoted by -. ARI = ARI target (Appendix B) SIL = Silhouette target (Appendix F)

APPENDIX N

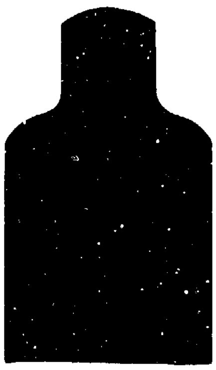
SCALED SILHOUETTE TARGET

(This target has been reduced in size
from 18 x 24 inches to 8 x 10-1/2 inches.)

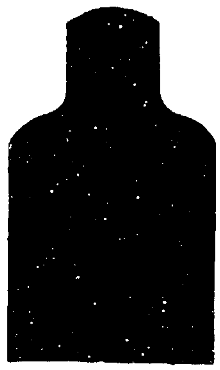
300 M



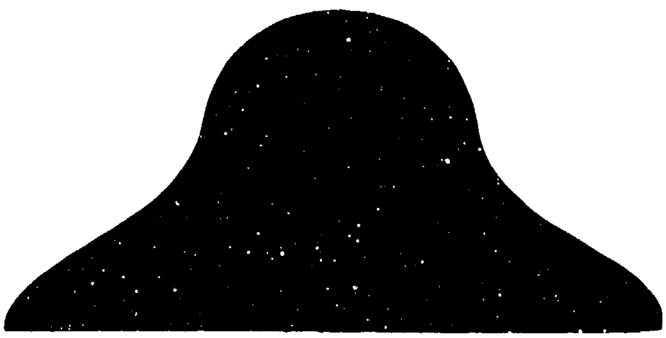
75 M



175 M



175 M



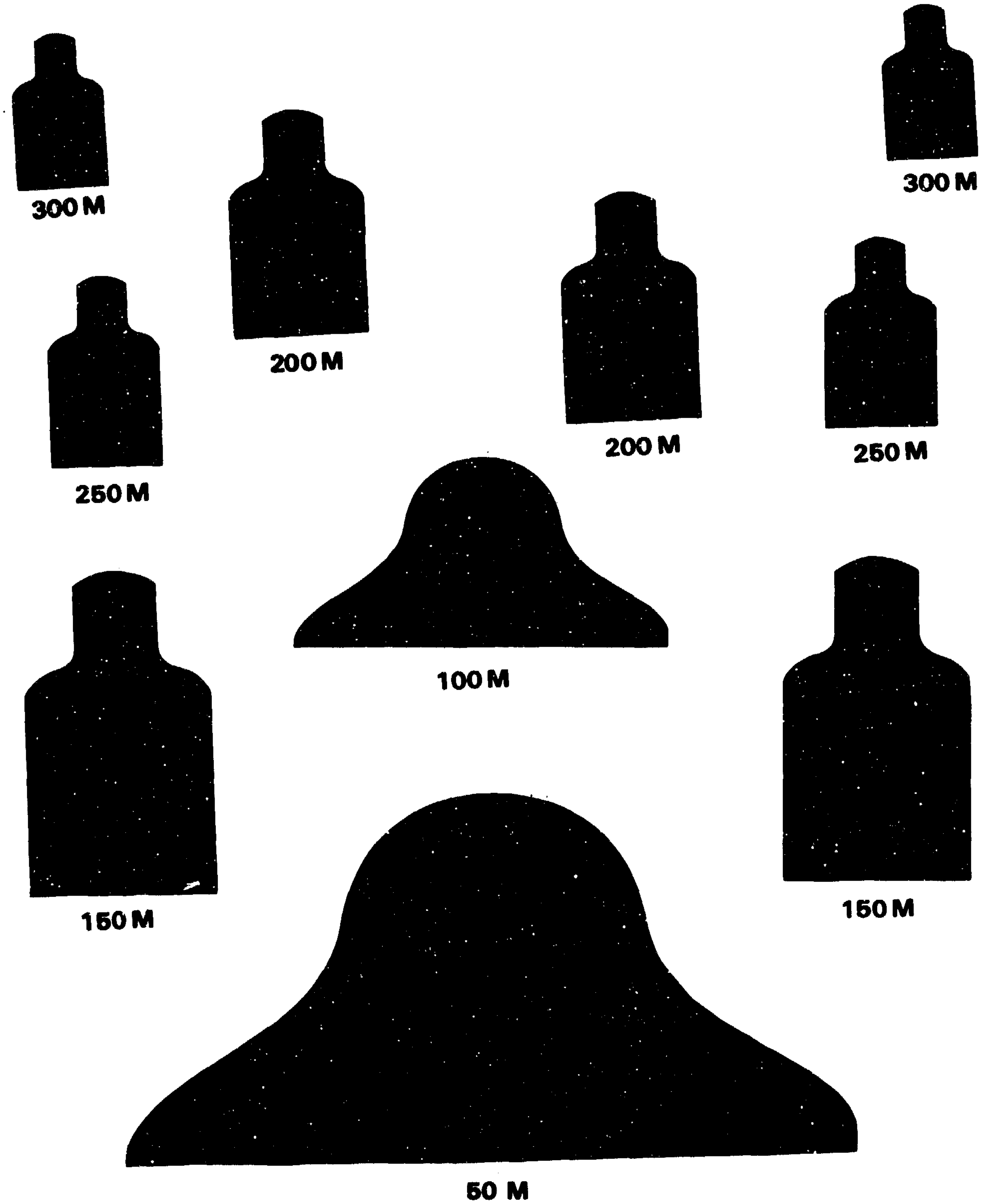
75 M

300 M

APPENDIX O

TIMED FIRE SCALED SILHOUETTE TARGET

(This target has been reduced in size from 18 x 24 inches to 8 x 10-1/2 inches.)

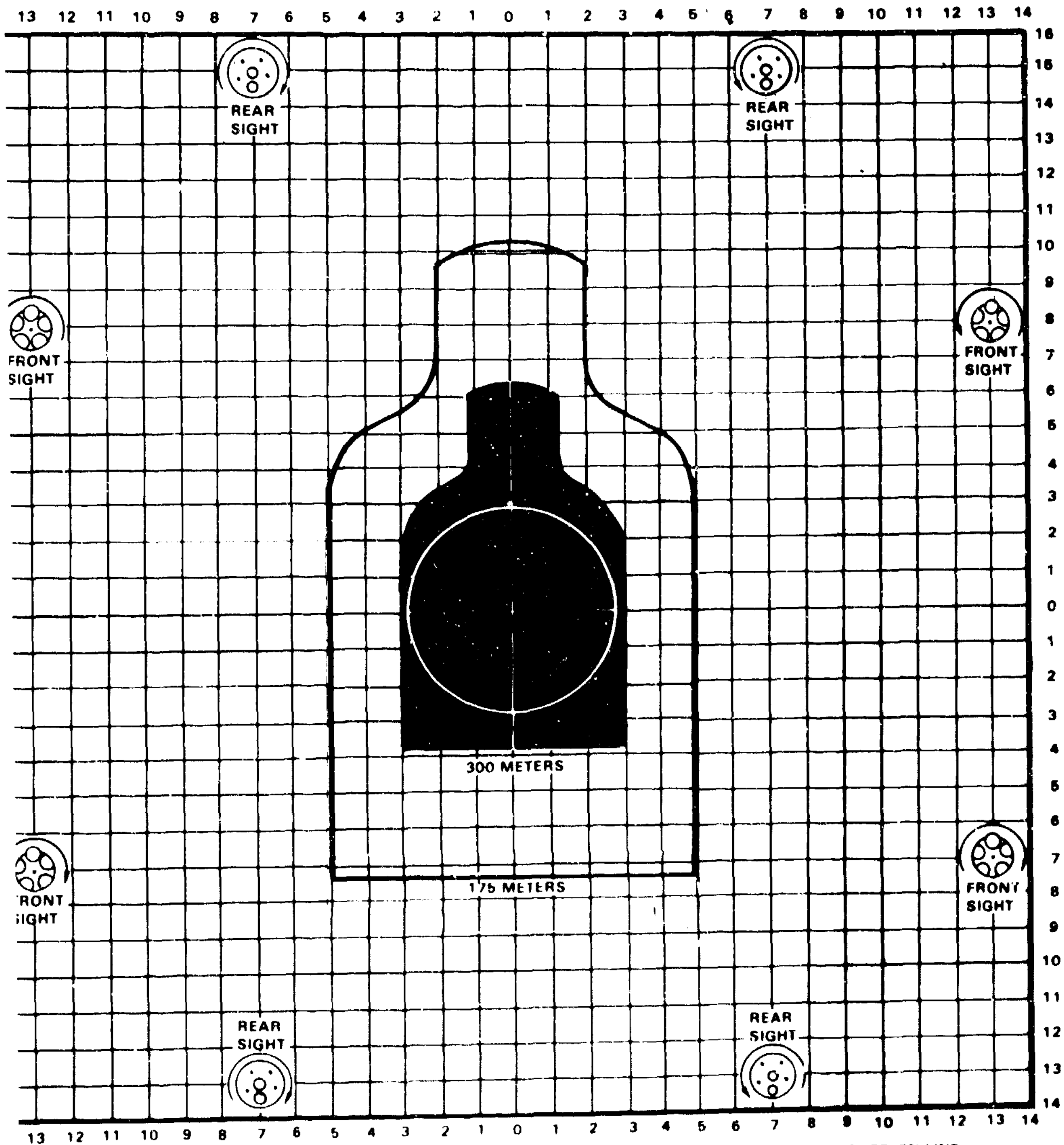

300 M
200 M
300 M
250 M
200 M
250 M
100 M
150 M
150 M
50 M

APPENDIX P

25 M SILHOUETTE ZEROING TARGET

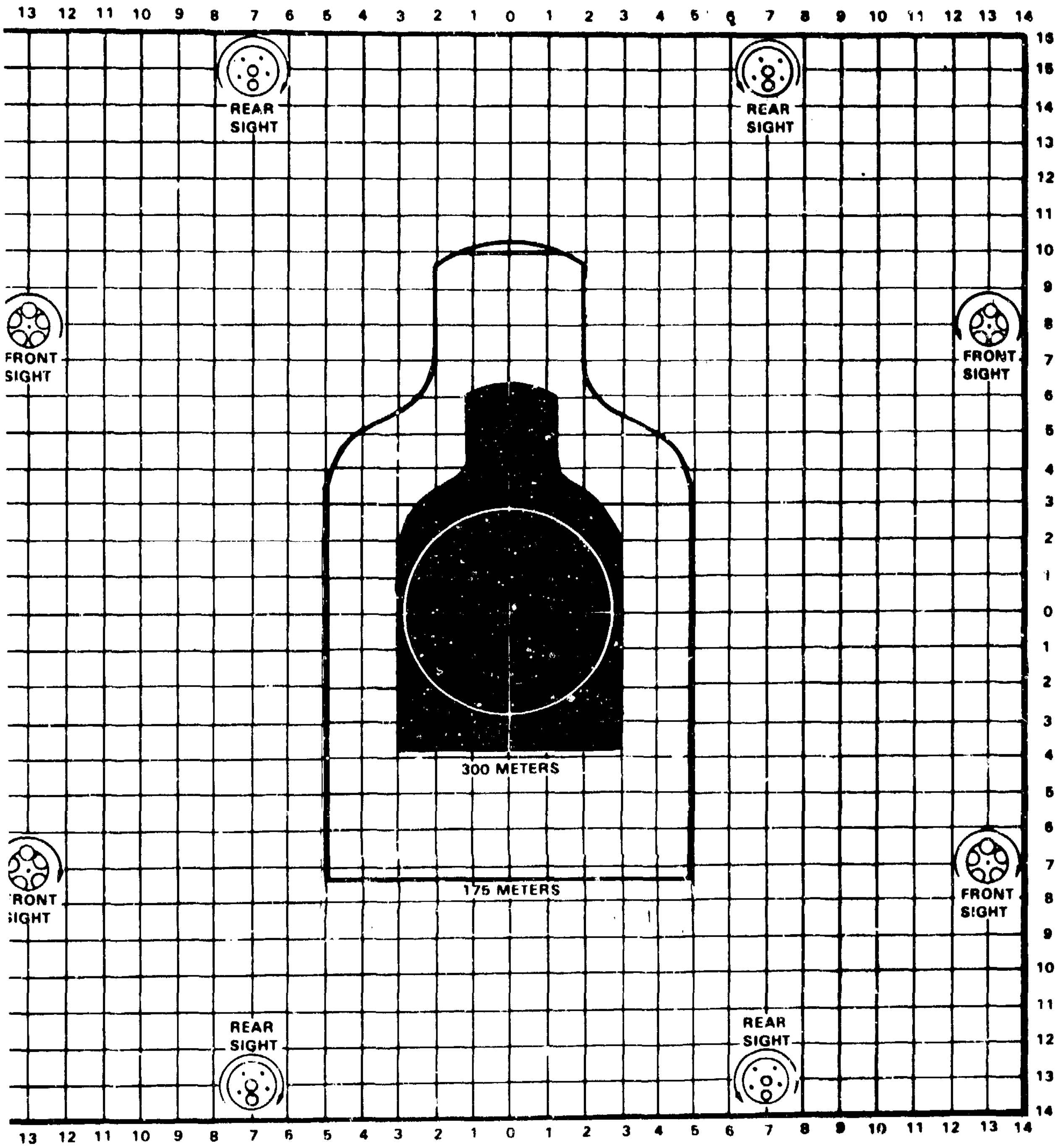
(The left side of this target has been cut to fit 8" width.)

ARI 25 METER ZEROING TARGET



TO ZERO MOVE SHOT GROUP CENTER TO THE DOT CLICK EACH SIGHT THE NUMBER OF TIMES MARKED ON LINE

ARI 25 METER ZEROING TARGET



TO ZERO MOVE SHOT GROUP CENTER TO THE DOT CLICK EACH SIGHT THE NUMBER OF TIMES MARKED ON LINE

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1 1ST INFANTRY DIVISION AND FT. RILEY ATTN: AFZN-DPT-T
1 CHIEF, ATTITUDE + OPINION SURVEY DIVISION ATTN: ATZI-NCR-MA, HOFFMAN BLDG II
1 USA INTELLIGENCE AND SECURITY COMMAND ATTN: IAOPS-TNG-T
2 HQ TRADOC TECHNICAL LIBRARY
1 NAVAL TRAINING EQUIPMENT CEN ATTN: TECHNICAL LIBRARY
1 MILITARY OCCUPATIONAL DEVELOPMENT DIRECTORATE ATTN: ATZI-NCR-MS-M, RM 3N33 HOFFMAN BLDG II
1 DATA ANALYSIS DIVISION ATTN: ATZI-NCR-MD, HOFFMAN BLDG II
1 USA MILPERCEN ATTN: DAPC-POO-T
1 8TH INFANTRY DIVISION
1 HQDA ARMY FORCE MODERNIZATION COORDINATION OFFICE
1 HQDA ATTN: DASG-PTB
1 1230 USARCOM RESERVE CENTER
1 US ARMY SOLDIER SUPPORT CENTER ATTN: ATSG-HDD (DR. CAVINESS)
1 USA FORCES COMMAND AFLG - DEPUTY CHIEF OF STAFF FOR LOGISTICS
1 US ARMY AIR DEFENSE SCHOOL ATTN: ATSA-DTD
1 DIRECTORATE OF TRAINING ATTN: ATZQ-T
1 DIRECTORATE OF COMBAT DEVELOPMENTS ATTN: ATZQ-D
1 HQDARCOM MARINE CORPS LIAISON OFC
1 DEPARTMENT OF THE ARMY US ARMY INTELLIGENCE + SECURITY COMMAND
1 USA MISSILE COMMAND ATTN: DRSMI-NTN
1 ARTADS ATTN: DRCPM-TDS-TD
1 USA FORCES COMMAND
1 PM TRADE /
1 US MILITARY DISTRICT OF WASHINGTON OFC OF EQUAL OPPORTUNITY
1 NAVAL CIVILIAN PERSONNEL COMD SOUTHERN FLD DIV
22 ARI LIAISON OFFICE
1 7TH ARMY TRAINING COMMAND
1 ARMY TRAINING SUPPORT CENTER INDIVIDUAL TRAINING EVALUATION
1 HQDA, DCSOPS INDIVIDUAL TRAINING
1 HQDA, DCSOPS TRAINING DIRECTORATE
1 HQDA, DCSLOG MAINTENANCE MANAGEMENT
1 HQDA, DCS STUDY OFFICE
1 U.S. NAVY TRAINING ANALYSIS EVALUATION GROUP
1 USACDEC ATTN: ATEC-EX-E HUMAN FACTORS
1 ATTN: SM-ALC/DPCR
1 USAFAGOS/TAC SENIOR ARMY ADVISOR
1 OASA (RDA) DEPUTY FOR SCIENCE AND TECHNOLOGY
1 OFC OF NAVAL RESEARCH /
1 AFHRL/LRT
1 AFHRL/LRLG
1 AIR FORCE HUMAN RESOURCES LAB ATTN: AFHRL/TSR
1 AFAMRL/BB
1 NAVY PERSONNEL R AND D CENTER DIRECTOR OF PROGRAMS
1 NAVY PERSONNEL R AND D CENTER /
2 OFC OF NAVAL RESEARCH PERSONNEL AND TRAINING RESEARCH PROGRAMS
1 NAVAL PERSONNEL R + D CENTER /
1 OFC OF NAVAL RESEARCH PROJECT OFFICER, ENVIRONMENTAL PHYSIOLOGY

1 NAVAL AEROSPACE MEDICAL RSCH LAB AIRBORNE RANGER RESEARCH
1 NAVAL AEROSPACE MEDICAL RSCH LAB AEROSPACE PSYCHOLOGY DEPARTMENT
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY ATTN: ATAA-TGA
1 HEADQUARTERS, COAST GUARD CHIEF, PSYCHOLOGICAL RSCH BR
1 USA RESEARCH AND TECHNOLOGY LAB ATTN: DAVDL-AS (DR. R. S. DUNN)
1 USA MOBILITY EQUIPMENT R AND D COMD ATTN: DRDME-TQ (SCHOOL)
1 NIGHT VISION LAB ATTN: DRSEL-NV-SDD
1 USA TRAINING BOARD ATTN: ATTG-ATB-TA
1 USA MATERIEL SYSTEMS ANALYSIS ACTIVITY ATTN: DRXSY-C
1 NAFEC HUMAN ENGINEERING BRANCH
1 USA ARCTIC TEST CEN ATTN: AMSTE-PL-TS
1 USA COLD REGIONS TEST CEN ATTN: STECR-OP
1 USA ELECTRONIC WARFARE LAB CHIEF, INTELLIGENCE MATER DEVEL + SUPP OFF
1 USA RSCH DEVEL + STANDARDIZA GP, U.K.
1 AFWAL/FIGR (CDIC)
1 USA RESEARCH AND DEVELOPMENT LABS CHIEF, BEHAV SCIENCES DIV, FOOD SCI LAB
1 NAVAL AIR SYSTEMS COMMAND ATTN: AIR-5313
1 USACDEC TECHNICAL INFORMATION CENTER
1 USAARL LIBRARY
1 USA TRADOC SYSTEMS ANALYSIS ACTIVITY ATTN: ATAA-SL (TECH LIBRARY)
1 UNIFORMED SERVICES UNIT OF THE HEALTH SCI DEPARTMENT OF PSYCHIATRY
1 GRONINGER LIBRARY ATTN: ATZF-RS-L BLDG 1313
1 CENTER FOR NAVAL ANALYSIS
1 NAVAL HEALTH RSCH CEN LIBRARY
1 NAVAL PERSONNEL R AND D CEN LIBRARY ATTN: CODE P106
1 AIR FORCE HUMAN RESOURCES LAB ATTN: AFHRL/OTS
1 HQ, FT. HUACHUCA ATTN: TECH REF DIV
1 USA ACADEMY OF HEALTH SCIENCES STIMSON LIBRARY (DOCUMENTS)
1 SCHOOL OF SYSTEMS AND LOGISTICS
1 DEPARTMENT OF THE NAVY TRAINING ANALYSIS AND EVALUATION GP
1 USMA DEPT OF BEHAVIORAL SCI AND LEADERSHIP
1 USA COMMAND AND GENERAL STAFF COLLEGE ATTN: LIBRARY
1 USA TRANSPORTATION SCHOOL USA TRANSP TECH INFO AND RSCH CEN
1 USA ADMINCEN TECHNICAL RESEARCH BRANCH LIBRARY
1 USA FIELD ARTY BD
1 INSTITUTE FOR DEFENSE ANALYSES
1 USA TRAINING SUPPORT CENTER ATTN: ATIC-DST-PA
1 AFHRL TECHNOLOGY OFC (H)
1 USA MOBILITY EQUIPMENT R AND D COMMAND ATTN: DRDME-ZG
1 DA US ARMY RETRAINING BDE RESEARCH + EVALUATION DIVISION
1 HUMAN RESOURCE MANAGEMENT CEN, SAN DIEGO
1 USAFA DEPT OF BEH SCI + LEADERSHIP
1 US MILITARY ACADEMY DEPT. OF HISTORY, BLDG 601
1 USA INTELLIGENCE CEN AND SCH ATTN: SCHOOL LIBRARY
1 USA INTELLIGENCE CEN AND SCH ATTN: ATSI-DT-DL
1 MARINE CORPS INSTITUTE
1 NAVAL SAFETY CENTER
1 US COAST GUARD TNG CEN ATTN: EDUCATIONAL SVCS OFFICER
1 USAAVNC AND FT. RUCKER ATTN: ATZQ-ES
1 US ARMY AVN TNG LIBRARY ATTN: CHIEF LIBRARIAN
1 USA AIR DEFENSE SCHOOL ATTN: ATSA-DT
1 USAAVNC ATTN: ATZQ-D
1 US MILITARY ACADEMY DIRECTOR OF INSTITUTIONAL RSCH
1 USAADS-LIBRARY-DOCUMENTS
1 USA SERGEANTS MAJOR ACADEMY ATTN: LEARNING RESOURCES CENTER
1 USA INFANTRY BOARD ATTN: ATZB-IB-AE
1 USA INTELLIGENCE CEN AND SCH ATTN: ATSI-DOTD-SF
1 USA ORDNANCE CEN AND SCH ATTN: ATSL-TD-TAC
1 USA ARMOR SCHOOL ATTN: ATZK-TD
1 USA ARMOR CENTER DIRECTORATE OF COMBAT DEVELOPMENTS
1 NAVAL POSTGRADUATE SCH ATTN: DUDLEY KNOX LIBRARY (CODE 1424)
1 USA TRANSPORTATION SCHOOL DEPUTY ASST. COMMANDANT EDUCA. TECHNOLOGY

1 USA SIGNAL SCHOOL AND FT. GORDON ATTN: ATZH-EV
1 USA QUARTERMASTER SCH ATTN: ATSM-TNG-TM-ET
1 USA MILITARY POLICE SCHOOL ATTN: LIBRARY
1 USA ARMOR CENTER + FT. KNOX OFFICE OF ARMOR FORCE MGT + STANDARDIZATION
1 CHIEF OF NAVAL EDUCATION AND TNG /
1 USA SIGNAL SCHOOL + FT. GORDON EDUCATIONAL TECHNOLOGY DIVISION
1 HQ ATC/XPTD TRAINING SYSTEMS DEVELOPMENT
1 USA INSTITUTE FOR MILITARY ASSISTANCE ATTN: ATSU-TD-TA
1 US ARMY ARMOR CENTER ATTN: ATZK-TD-PMO
1 USA AIR DEFENSE CENTER, FT. BLISS ATTN: ATZC-DIM
1 USA QUARTERMASTER SCHOOL DIRECTORATE OF TRAINING DEVELOPMENTS
1 US COAST GUARD ACADEMY /
1 USA TRANSPORTATION SCHOOL DIRECTORATE OF TRAINING + DOCTRINE
1 USA INFANTRY SCHOOL LIBRARY /
1 USA INFANTRY SCHOOL ATTN: ATSH-I-V
1 US ARMY INFANTRY SCHOOL ATTN: ATSH-CD
1 USA INFANTRY SCHOOL ATTN: ATSH-DOT-LRD
1 USA INFANTRY SCHOOL ATTN: ATSH-EV
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN ATTN: ATZN-PTS
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, COMBAT DEVELOPMENT
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN DIR, TRAINING DEVELOPMENT
1 USA MP + CHEM SCH/TNG CEN + FT. MCCLELLAN ATTN: ATZN-MP-ACE
1 USA INSTITUTE OF ADMINISTRATION ATTN: RESIDENT TRAINING MANAGEMENT
1 USA FIELD ARTILLERY SCHOOL MORRIS SWETT LIBRARY
1 USA INSTITUTE OF ADMINISTRATION ACADEMIC LIBRARY
1 USA WAR COLLEGE ATTN: LIBRARY
1 USA ENGINEER SCHOOL LIBRARY AND LEARNING RESOURCES CENTER
1 USA ARMOR SCHOOL (USARMS) ATTN: LIBRARY
1 US COAST GUARD ACADEMY LIBRARY
1 USA TRANSPORTATION SCHOOL TRANSPORTATION SCHOOL LIBRARY
1 ORGANIZATIONAL EFFECTIVENESS CEN + SCH ATTN: LIBRARIAN
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-TD
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-RM-M
1 US ARMY INTELLIGENCE CENTER + SCHOOL ATTN: ATSI-DT-SF-IM
1 US MARINE CORPS EDUCATION CENTER
1 USA FIELD ARTILLERY SCHOOL DIRECTORATE OF COURSE DEV + TRAINING
1 DEPARTMENT OF THE AIR FORCE AIR UNIVERSITY LIBRARY (ATC)
1 USA CHAPLAIN CENTER + SCHOOL ATTN: ATSC-TD-OD
1 USA CHAPLAIN CENTER + SCHOOL ATTN: ATSC-TD-ED
1 USA CHAPLAIN CENTER + SCHOOL ATTN: ATSC-TD-SF
1 USA CHAPLAIN CENTER + SCHOOL ATTN: ATSC-DOS-LLC
1 HQ TRADOC TRAINING DEVELOPMENT INSTITUTE
2 BRITISH EMBASSY BRITISH DEFENCE STAFF
2 CANADIAN JOINT STAFF
1 CDLS (W) LIBRARY
1 FRENCH ARMY ATTACHE
1 AUSTRIAN EMBASSY DEFENSE, MILITARY AND AIR ATTACHE
3 CANADIAN DEFENCE LIAISON STAFF ATTN: COUNSELLOR, DEFENCE R AND D
1 ROYAL NETHERLANDS EMBASSY MILITARY ATTACHE
1 CANADIAN FORCES BASE CORNWALLIS ATTN: PERSONNEL SELECTION
2 CANADIAN FORCES PERSONNEL APPL RSCH UNIT
1 ARMY PERSONNEL RESEARCH ESTABLISHMENT
6 LIBRARY OF CONGRESS EXCHANGE AND GIFT DIV
1 DEFENSE TECHNICAL INFORMATION CEN ATTN: DTIC-DDA-2
140 LIBRARY OF CONGRESS UNIT DOCUMENTS EXPEDITING PROJECT
1 US GOVERNMENT PRINTING OFC LIBRARY, PUBLIC DOCUMENTS DEPARTMENT
1 US GOVERNMENT PRINTING OFC LIBRARY AND STATUTORY, LIB DIV (SLL)
1 THE ARMY LIBRARY ATTN: ARMY STUDIES SEC
3 ROYAL ARMY EDUCATIONAL CORPS CENTRE ARMY SCHOOL OF TRAINING SUPPORT
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